METAL ALLOYS FOILING FORGERS PLASTIC BANKNOTES

MINTING & PRINTING

COINS AND BANKNOTES ARE still very much in demand, despite the growing popularity of cheques and credit cards. So banknote printers have to take a lot of trouble to deter people from forging paper money.

But most coins are worth so little these days that crooks no longer bother faking them.

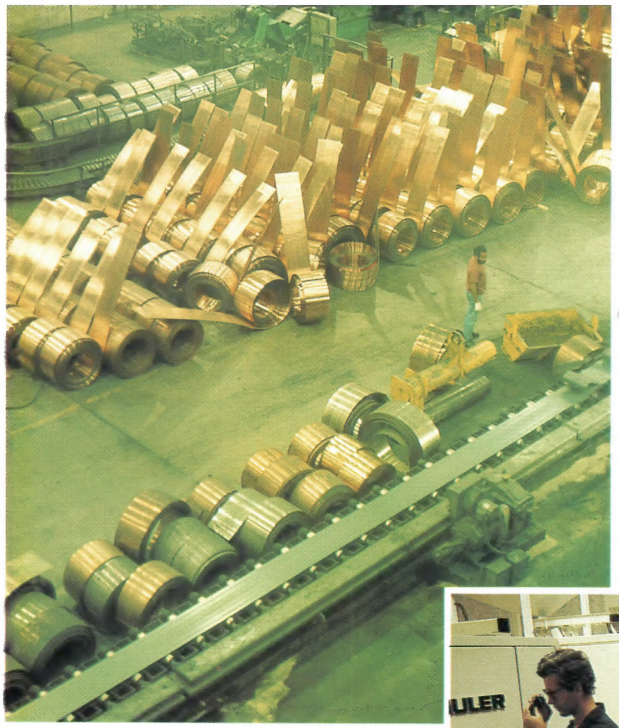
Different countries use different metals for their coins. In Britain, Ireland, Australia and New Zealand, for instance, the 'copper' coins are made of bronze, while the 'silver' coins are made of a metal called cupronickel. In the USA, traditional copper cents have been replaced by copper-plated zinc coins, and the silver dollars by cupronickel ones.

Bronze and cupronickel are alloys – mixtures of metals rather than

***Finished coins** are washed and dried in the top drum, then poured into the hopper of the counting machine. Printed notes (inset below) are counted automatically.*

Royal Mint

George Bernard/Science Photo Library



Spectrum Colour Library

***Philadelphia Mint**, in the USA, is the largest in the world, producing 8 billion coins a year. To cope with the very high production speeds, coinage metal is fed into the blanking machine from continuous coils. After minting, the coins go through the quality control stage (inset below). Sample coins are weighed and a few, chosen at random, are given a visual inspection using a magnifying glass.*

Spectrum Colour Library

pure ones. The exact proportions of each metal in the alloy are carefully chosen so that the final coins will look right – many countries still want their coins to look like silver or gold – and be hard-wearing.

Coinage bronze consists of around 97 per cent copper, 2.5 per cent zinc and 0.5 per cent tin. Cupronickel contains around 80 per cent copper and 20 per cent nickel. Many high value coins that look like gold are made of 70 per cent copper, 5 per cent nickel and 25 per cent zinc.

Minting coins

The first stage in minting coins is to produce the metal. The pure metals, such as copper, zinc and tin, are melted together in a small electric furnace in the correct proportions to make the alloy for the coins.

When the furnace is tapped, the alloy is cast into slabs about 210 mm wide and 13–19 mm thick. These are then cut into 10 metre lengths weighing up to 350 kg each. Next, the lengths are passed through a rolling mill where they are first reduced to about 3 mm thick and then to slightly more than the thickness of the coins being made.

Re-cycled scrap

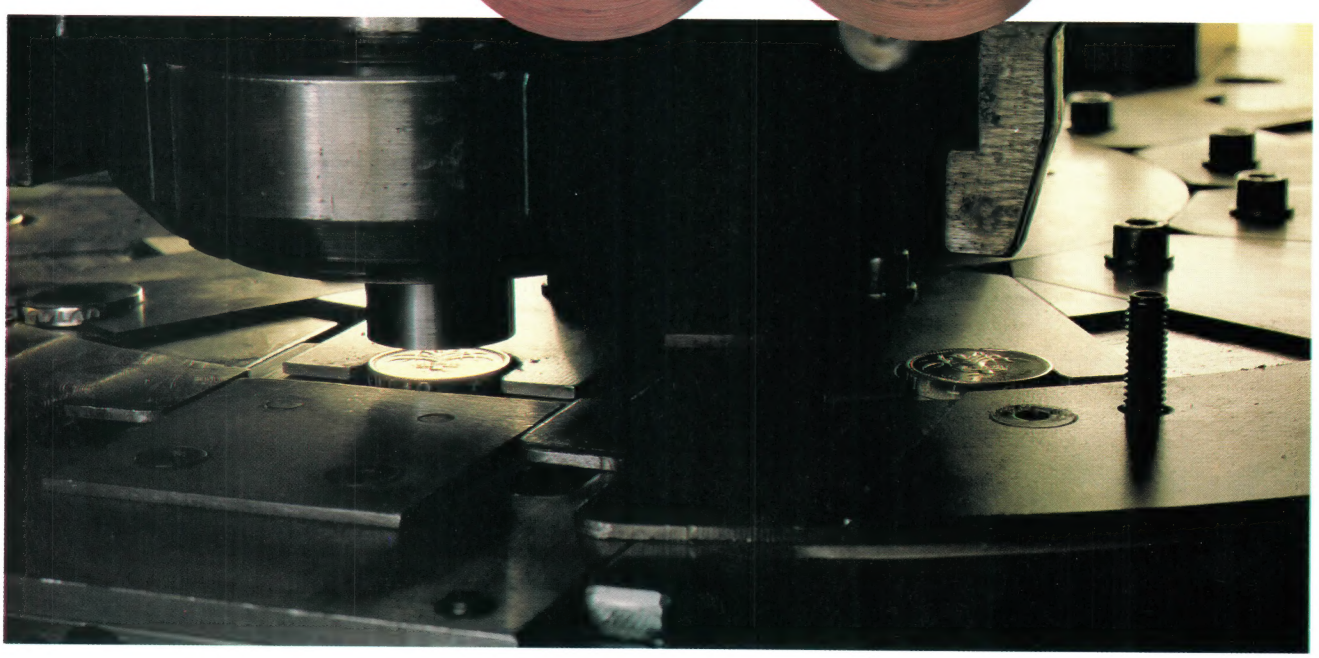
After rolling, the metal is fed into blanking presses, which punch out discs of metal called blanks. The perforated metal scrap left after the blanks have been punched out is returned to the furnaces to be melted down and re-used again. The blanks go on to rimming machines, which slightly increase the thickness of the outside edge by squeezing the blanks between a pair of rollers.

After the bashing it gets during the rolling, blanking and rimming stages, the metal of the blanks becomes too hard for further working. So the next operation is to anneal (or soften) the blanks in a gas-fired furnace at 750°C if they are bronze, or 900°C if they are cupronickel. After that, they are allowed to cool slowly to complete the softening process, cleaned with acid to remove any stains, then rinsed and dried.

The final stage is where the blanks are made into finished coins. To do this, they are squeezed from above and below between pairs of steel dies (steel moulds), each of

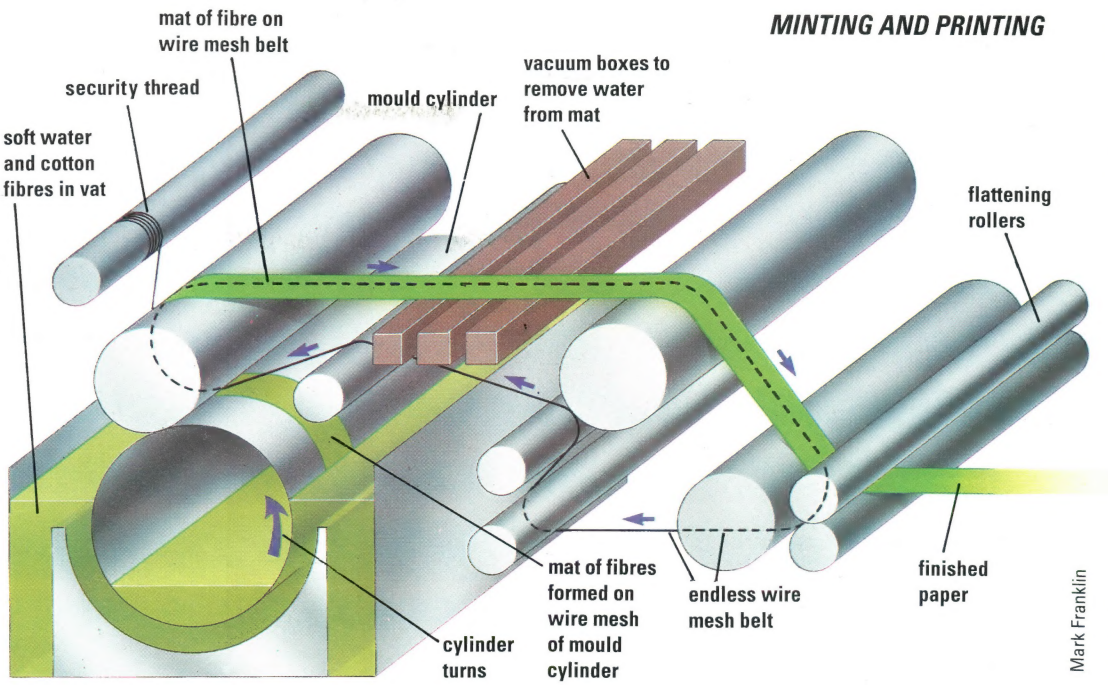
Spectrum Colour Library

***Coin dies** carry the design in reverse so that the finished coin reads correctly. Many sets of dies are fitted to the minting machine (below). The dies are carried round from the magazine where the blanks are loaded to striking and infra-red inspection positions.*



Royal Mint

Banknote paper *is made on a machine 200 metres long. The wet cotton fibres are picked up on the mesh surface of the mould cylinder as it revolves in a vat of water and fibres. The mat of wet fibres is transferred to a wire mesh belt where some water drains off. Next, it passes through rollers, which flatten and polish the surface, before it is dried.*



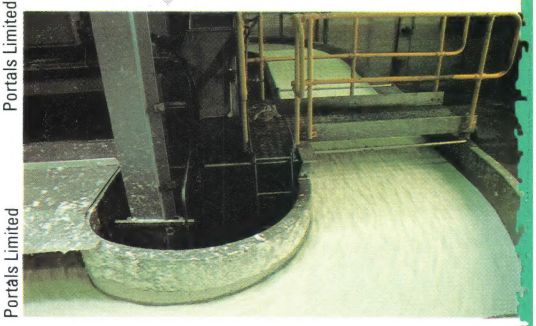
Mark Franklin

Ray Duns

Metal security strips *can be added to the wet paper while it is still clinging to the mould cylinder. The latest 'window' strips are difficult to forge.*

Watermarks *are made while the fibres are on the mould cylinder. The design is picked up from patterns on the wire mesh surface.*

Old denim jeans, *worn out vests and all sorts of other cotton rags are used to make banknote paper. The rags are broken down into fibres with powerful chemicals and are carried to the paper-making machines on water.*



Portals Limited

Portals Limited

which has the design of one side of the coin cut into it.

On the minting machine, a blank is automatically placed on the bottom die and held in place by a collar. The inside of the collar carries the design, if any, that will appear around the edge of the finished coin.

With the blank in place between them, the two dies are squeezed together in a hydraulic press using a force of up to 150 tonnes. This force is so great that the metal almost melts for a moment. The pressure forces the metal outwards so it fills the die completely and the rim picks up the shape and design on the inside of the retaining collar.

Next, the dies open and the coin is automatically ejected. A fresh blank is then inserted and the process starts again. The working life of a set of steel dies (which may operate at speeds of up to 600 coins a minute) is about 200,000 coins.

The Royal Mint at Llantrisant, South Wales, produces all the coins for the United Kingdom, as well as making coins and medals for 60 overseas countries. The United States has two separate mints, one in Philadelphia, Pennsylvania and the other one at Denver, Colorado.

Banknotes

When the first colour photocopiers came out, the thought of getting rich by photocopying money probably crossed the minds of many people. However, early colour photocopies were not good enough to fool anyone, and the law takes a dim view of that sort of thing – forgers usually get locked away for years.

In fact, the banks that issue banknotes take great care to ensure that forging them is extremely difficult and expensive. The three main things about banknotes that make them hard to fake are: the special paper that is used, the complicated printing processes involved and the intricate designs. New technologies, such as making banknotes from plastic instead of paper, will make life even more difficult for forgers in the future.

There is just one company in the world that specializes in making banknote paper and it only supplies the paper to authorized banknote printers – for obvious reasons. While the paper is being made, two additional anti-forgery features can be added if required.

One is the watermark – these are formed on the papermaking machine. A wire mesh leaves a translucent design in the fibres of the paper while it is still wet. To find the watermark, look for a blank patch in the design; hold the note up to the light and you will see the watermark inside the blank patch. The other anti-forgery feature is a thin metal strip called a security thread, which is sometimes embedded in the paper.

Hand engraving

The printed design on a banknote is usually a complicated mixture of portraits, pictures and geometric

Just amazing!

MONEY TO BURN

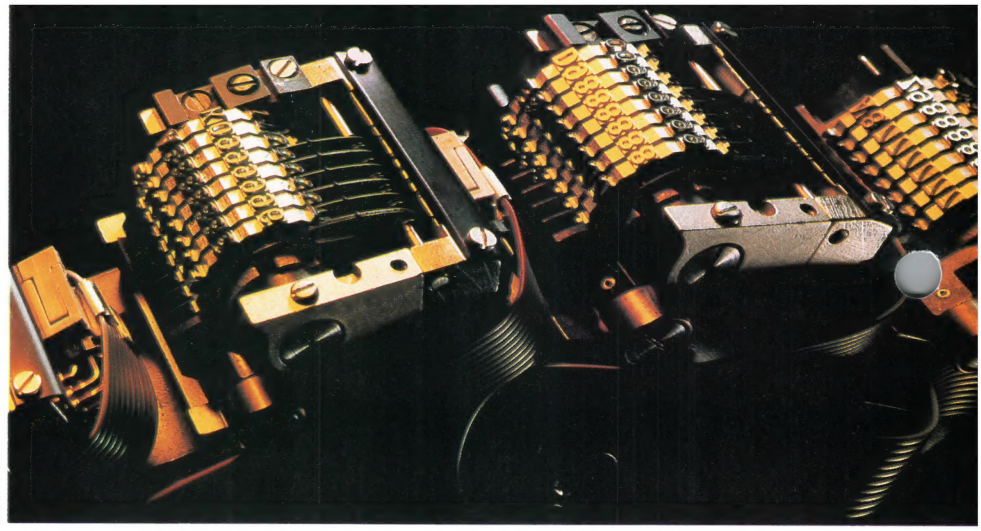
THE CENTRAL HEATING AT THE BANK OF ENGLAND PRINTING WORKS IS FIRED BY BURNING OLD BANK NOTES THAT HAVE BEEN WITHDRAWN FROM USE. AT LEAST 4 MILLION OF THEM ARE BURNT EVERY WORKING DAY.

Paul Raymonde

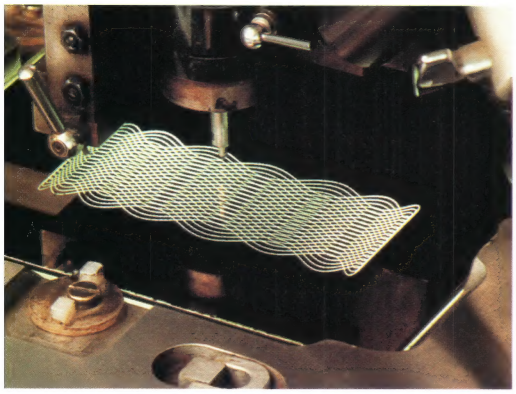
patterns. Much of the design work is done by computer-aided design (CAD) equipment, but the main portraits are hand-drawn by artists, then transferred to a steel block by a highly-skilled engraver.

The engraving is made by cutting lines into a block of steel and is done entirely by hand. It can take many months to produce the engraving of a single portrait and the detail is so fine the engraver has to use a microscope to see it. The tools used are very similar to lino-cutting tools.

The master copy of the design is then transferred to the printing plates, which are often chrome-plated to give them a very long life on the printing press.



De la Rue



Bank of England

Numbering heads *are used to print the serial numbers on notes. The numbers change automatically after printing each note. They also trigger an electronic read-out which counts the number of notes printed.*

Geometric *background patterns are engraved on the printing plates using a computer-controlled machine that puts in random variations. The irregularity of the final pattern is difficult for forgers to copy.*

The main portraits are printed afterwards, by a process called intaglio, and the image is sunk into the surface of the printing plate. Thick printing ink is spread across the plate and the surplus is then removed using a thin steel blade that scrapes the surface. This leaves ink in the fine grooves. The paper passes through rollers that press the paper into the grooves.

The paper picks up the ink, forming printed lines that are slightly raised above the surface of the paper. If you take a new banknote and rub it lightly between your thumb and forefinger, you can feel the raised printing.

One way to make banknotes last longer would be to make them out of plastic rather than paper. This has been done in Australia, where the first plastic note was issued in 1988. These notes are equipped with a new type of anti-forgery feature that looks like a hologram.

FOILING THE FORGERS

Laser copiers now produce excellent copies in full colour. What is more, they can be programmed to modify the output until the copies exactly match.

Forgers soon spotted that one of these laser copiers would produce excellent forged banknotes, without the trouble of engraving printing plates. To counter this threat, special fluorescent inks are now being used to print banknotes. These inks produce a bright light when examined in a special cabinet under ultraviolet light. The cabinets allow bank employees and the police to examine the notes without any danger of skin burns from the light.

A Canadian team has developed a way of making very thin, transparent strips of zirconium dioxide. These will be stuck on banknotes and show brightly-coloured patterns when looked at from an angle.

Spectrum Colour Library

Ray Duns

Banknote printing involves a combination of printing methods – something else that makes forgery difficult. The background designs are usually printed on a specially-modified offset litho newspaper press. The ink is transferred to the paper by a springy rubber blanket.

Plastic Australian banknotes *feel similar to paper ones but last much longer. They have an Optically Variable Device (OVD) in the top right hand corner to deter forgers. Printing on the plastic is difficult.*

BLACK GOLD

Q FOSSIL FUEL

Q OPEC

Q PETRODOLLARS

OIL EQUALS MONEY FOR most of the world today. Any change in the price of oil has an enormous impact on the economies of nations which, in turn, will affect everyone's lives.

Crude oil is a complicated mixture of hydrocarbons – compounds made up of carbon and hydrogen. From it, we get the fuels for our cars, trucks, planes and diesel trains, and we use it to heat buildings and generate electricity. It also provides the raw materials from which we make an enormous range of goods, including chemicals, plastics, detergents, waxes, paints and dyes, adhesives, explosives and medicines.

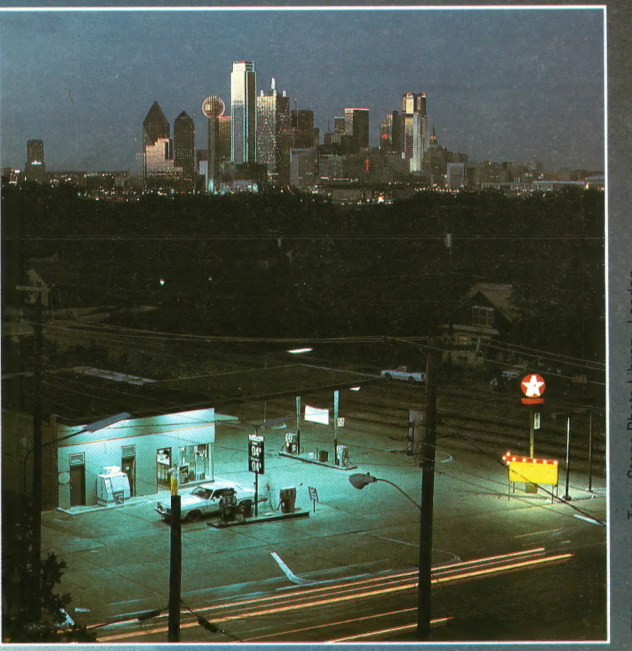
This source of energy we take so much for granted is the product of millions of years of evolution. The remains of plants and tiny animals settled at the bottom of prehistoric seas and were gradually covered with thick layers of mud. Over many thousands of years, the mud hardened into rock and the plant and animal remains beneath it decomposed into the thick, black liquid we know as petroleum, or crude oil.

Oil is an essential commodity. Any shortages, or increases in its price, can make oil producers richer and their customers poorer.

Black money

Oil is priced in US dollars per barrel: a barrel of oil being 42 US gallons (159 litres). The dollars paid to the producers for their oil are nicknamed 'petrodollars'. With world oil production running at about 65 million barrels a day, there are a lot of petrodollars flowing into the bank accounts of oil-producing countries.

From the end of World War II (in 1945) to the late 1960s, the price of oil was controlled by the major Western oil companies. These oil



ZEFA Tony Stone Photo Library, London

***The snowy wastes** of Alaska are rich in oil. The USA is the second largest oil producer, but also the leading importer, because petrol consumption is very high (inset above).*

Popperfoto/AFP

***An oil refinery** south of Kuwait City set alight by Iraqi Troops continues to burn and plunges the area into pitch blackness.*

companies were dominated by the so-called Seven Sisters: the American companies Esso, Gulf, Texaco, Mobil and Chevron, BP of Britain and the British-Dutch company, Shell.

During the 1960s, the oil-producing countries began to take more control of their valuable oil resources.

OPEC (Organization of Petroleum Exporting Countries) was set up in 1961 to protect the interests of a group of oil-producing nations, consisting of Iran, Iraq, Kuwait, Saudi Arabia and Venezuela. Since then, Algeria, Ecuador, Gabon, Indonesia, Libya, Nigeria, Qatar and the United Arab Emirates have joined them.

In 1970, Libya, led by Colonel Gadaffi, made the oil companies raise the price of its oil and cut back on production. The other OPEC countries soon followed Libya's example and within a couple of years it was OPEC, not the Seven Sisters, that controlled the price of oil.

In late 1973, as a retaliatory measure in the Arab-Israeli war, the OPEC members raised the price of their oil from $3 to $5.12 a barrel. They also cut back on their oil production, to create a world-wide shortage of oil, which gave them more control over the price throughout the 1970s.

These price increases brought huge sums of money to the OPEC countries, in particular to the Arab states and Iran. In effect, this money was being taken out of the Western countries and put into the oil-producing countries, making them, for a time, staggeringly rich.

Oil crisis

A second world oil crisis, much worse than the first, came in 1979. The Iranian oilfields were shut down for a time after the revolution there. This caused a shortage of oil, which pushed the price up to over $30 a barrel.

The high oil prices had a bad effect on the already weak industries of the West. The demand for oil fell as factories closed and unemployment rose. In addition, Western countries were finding ways to use less oil. They were also using more coal, natural gas and nuclear power instead of oil.

At about the same time, new oilfields were being developed by non-OPEC countries, such as Mexico, the former Soviet Union, Britain and Norway.

New competition

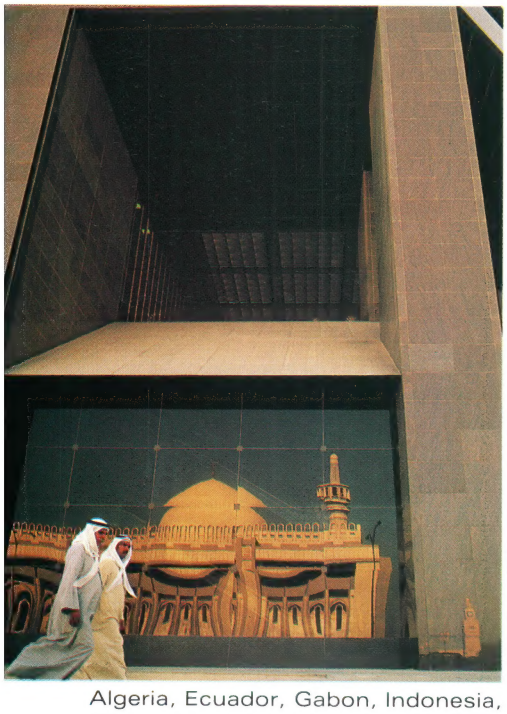
These factors helped bring the price of oil down, and by 1989, it was only about $14 a barrel. This was good news for the countries that had to buy oil, but not so good for the producers, including the OPEC countries. The Iran-Iraq War in the 1980s, together with Iraq's invasion of Kuwait in 1990, followed by its subsequent defeat in 1991, further disrupted OPEC production.

OPEC's share of world oil production fell from around 55 per cent in 1973 to about 40 per cent in 1992. Apart from Saudi Arabia, the world's two largest producers in 1992 were the USA with 13 per cent and Russia with 12.5 per cent of the world total.

***Millions of litres** of oil are carried across the seas by specially built supertankers to the oil hungry nations of the world. However, when oil producers become victims of war, they can cut off vital supplies and sea routes.*

Tony Stone Photo Library, London

***An ancient culture** is reshaped by the sudden and immense wealth brought to many Arab countries by their oil wells. But when Arabs import Western luxuries with petrodollars, they also contribute to the economies of the exporting nations.*



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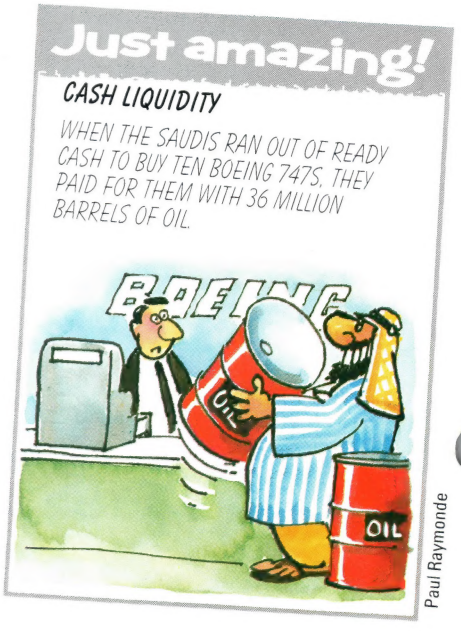
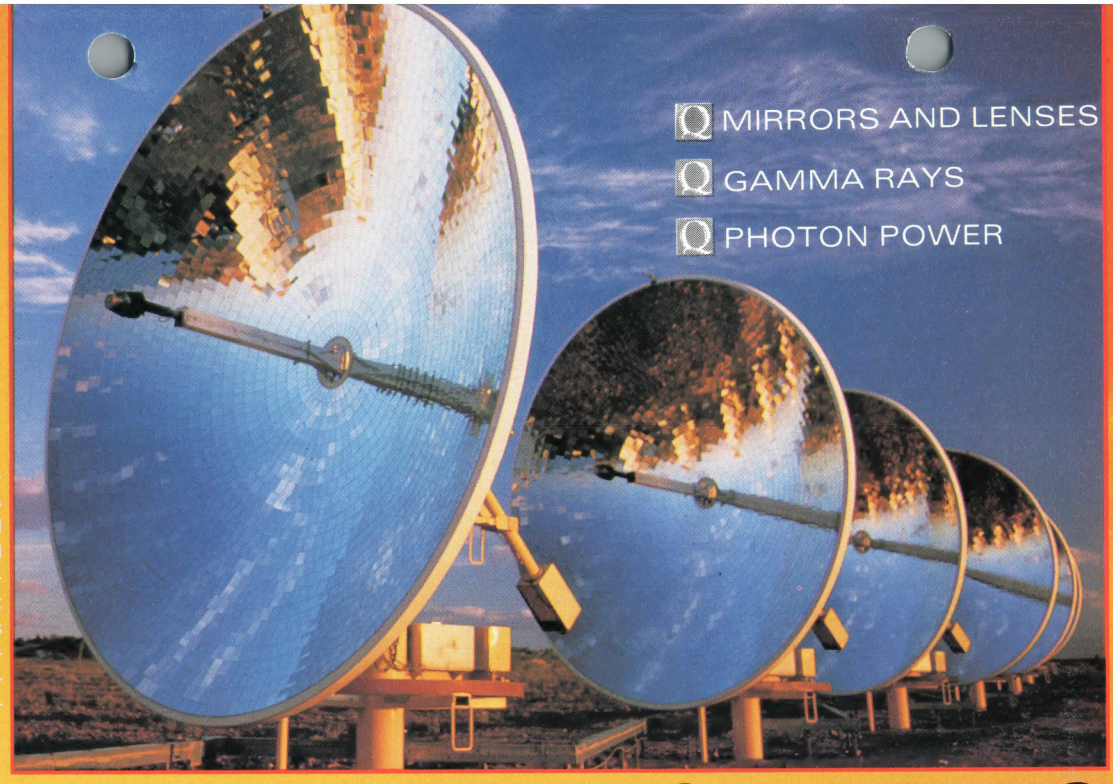


Paul Raymonde



- MIRRORS AND LENSES
- GAMMA RAYS
- PHOTON POWER

Tony Stone Photo Library, London

UNDERSTANDING LIGHT

LIGHT ITSELF IS INVISIBLE – the beam of light you see from a cinema projector is only reflection from dust or smoke in the air. It is only when light is reflected directly on to the retina that human beings can be said to 'see'.

This is only one of the paradoxes of the nature of light, which have fascinated scientists and philosophers over the centuries.

The sense of sight

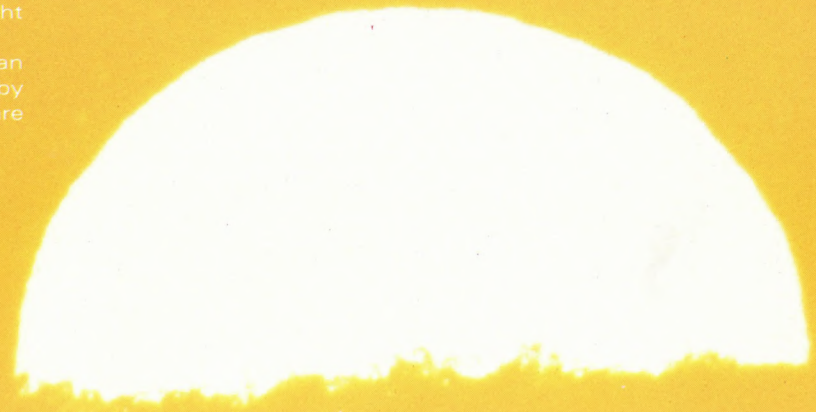
Sight is the most important of our senses, but the spectrum of colours we see is just a small part of the full electromagnetic spectrum. Other types of electromagnetic waves – such as radio waves, infra-red and ultraviolet radiation and x-rays – have wavelengths too short or too long to be detected by the human eye.

All electromagnetic waves carry energy. The energy carried by sunlight can easily be detected by laying any dark, light-absorbing material out in the Sun. This will heat up far more rapidly than a light material, which reflects light.

The energy carried by light can also be converted into electricity by solar cells. The most common are made from gallium arsenide and silicon. The light dislodges electrons from these semiconducting materials, which flow as an electric current.

Light can be converted into chemical energy too. The energy is captured by the green chlorophyll in the leaves of plants. The chemical reaction that this fuels produces food, turns carbon dioxide in the atmosphere into oxygen and is the source of all life on Earth.

Sir Isaac Newton (1642–1737) thought light was a stream of particles – pointing to the fact that rays of light travel in straight lines and reflect in an almost mechanical fashion. His theory was largely superseded by the wave theory put forward by Christopher Huygens (1629–95). This explained the phenomena of refraction and defraction, which held good for two centuries.



Frank Whitney/Image Bank

***The Sun** is the source of all life on Earth. Solar energy can be collected by solar dishes (inset above) to generate electricity.*

Alex Bartel/SPL

***Chlorophyll** in the leaves of trees captures the blue and red components of sunlight and chemically converts them into food energy.*

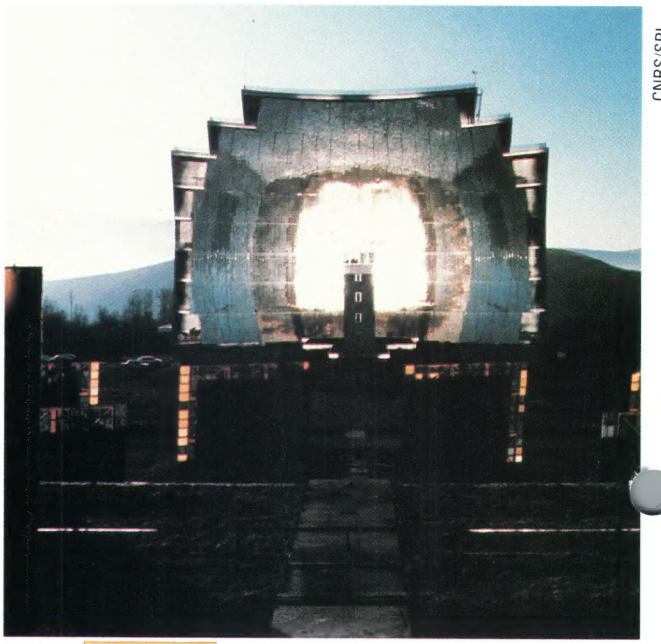
depends on its wavelength. The shorter the wavelength the higher the energy, the longer the wavelength the lower the energy of the photon.

The electromagnetic spectrum ranges from high energy gamma rays, produced during the decay of radioactive elements, through X-rays, made when electrons are rapidly accelerated or decelerated, to the ultraviolet and visible light, emitted or absorbed when electrons move from one energy level to another within an atom. Beyond visible light there are the infra-red and microwaves, which are also produced by the movement of electrons within atoms and then radio waves, generated by the rapid oscillation of electrons.

The wavelength of gamma rays and X-rays are the shortest, ranging from 0.0001 nm up to 1nm (1 nm or nanometre is one thousand millionths of a metre, or 10^{-9} m). The ultraviolet ranges from around 5 nm to 400 nm.

A range of colour

Next comes visible light with the familiar range of colours – violet, indigo, blue, green, yellow, orange and red – whose wavelengths range from 400 nm to 770 nm. Infra-red wavelengths range from 750 nm (0.75 μm or micrometers) to 1 mm.



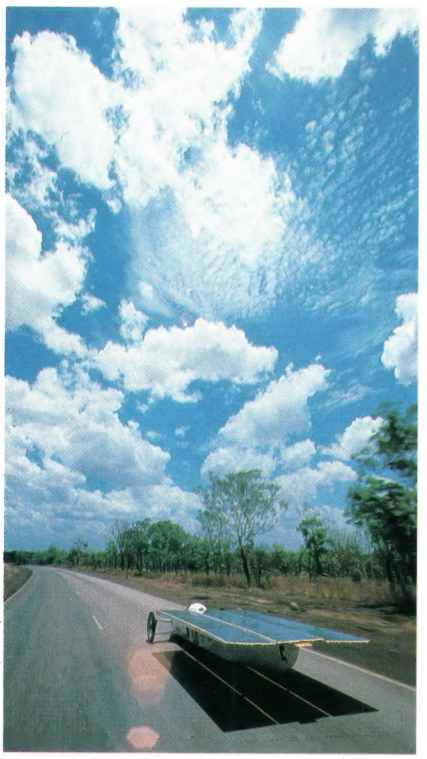
CNRS/SPL

***This solar furnace** in southern France uses over 180 sq metres of mirrors to focus sunlight. Temperatures of 4,000°C produced can melt up to 3 tonnes of steel at a time.*

Around the turn of this century though, certain atomic phenomena were discovered that could only be explained if light occurs in small, discrete amounts – particles again. It took the genius of Albert Einstein (1879–1955) to propose that light consists of tiny packets of waves, later known as photons. This explains why light behaves like a wave in some ways and as particles in other ways.

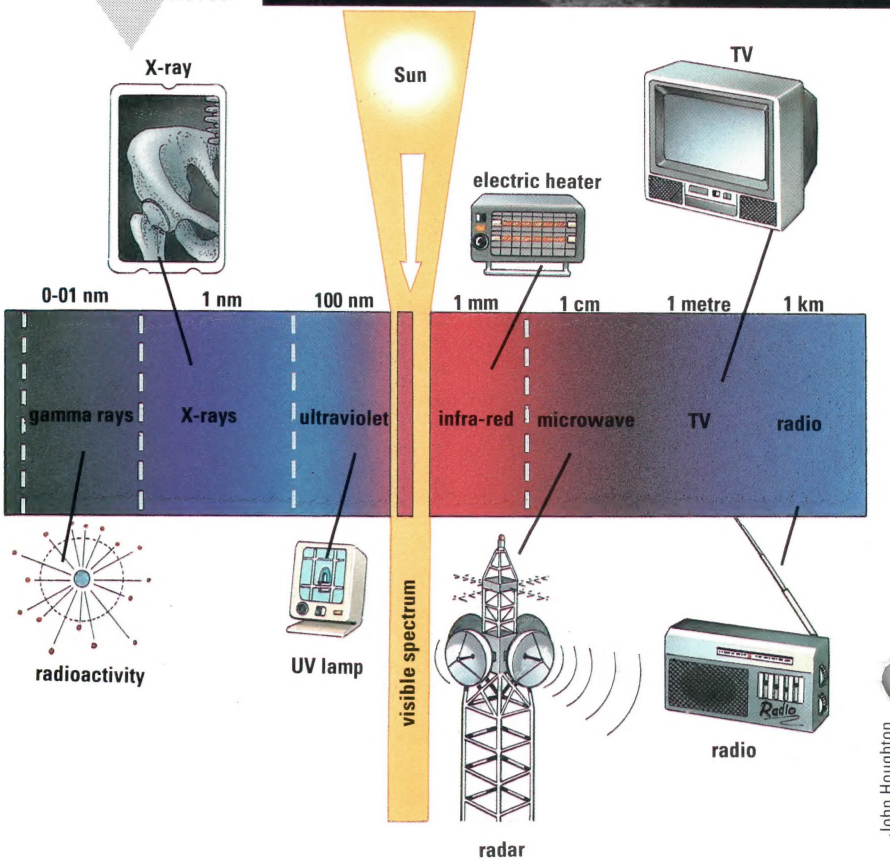
The energy of an individual photon

***Visible light** forms just one small part of the light spectrum, which extends from high energy gamma rays to low energy radio waves.*



Simon Bruty/Allsport

***A solar-powered car** takes to the road in Australia. The entire roof of the car is a solar collecting panel.*



John Houghton

Microwaves have wavelengths between 1 mm and 3 cm. Radio waves have wavelengths from 3 cm upwards. One of the longest radio wavelengths used for broadcast transmissions is 1500 m on the long waveband of most radios. Even longer wavelength radio transmissions are used to transmit radio signals to submarines when they are underwater. To transmit these signals aerials many hundreds of metres long are needed.

Bouncing light

Visible light occupies only a tiny part of the electromagnetic spectrum; without modern equipment we are blind to all the other radiation around us.

Light waves travelling through air are reflected back by an ordinary mirror with a silvered glass back. The image we see in the mirror is known as a 'virtual image' because – unlike the real image of an object – it is formed by the apparent rather than the actual convergence of light rays.

Reflected light bounces off a flat surface at the same angle as it hits it and is also in the same plane. Thus light hitting a mirror at 45° is reflected back at 45°.

The image in a flat mirror is flipped horizontally so that it appears that your left eye is the mirror image's right eye. It is odd to think that in a mirror we never see ourselves as others see us in reality. The only way to do that is to look at a photograph, TV or film picture. The image also appears the same distance behind the mirror as the object is in front of it and therefore looks the same size.

Curved mirrors

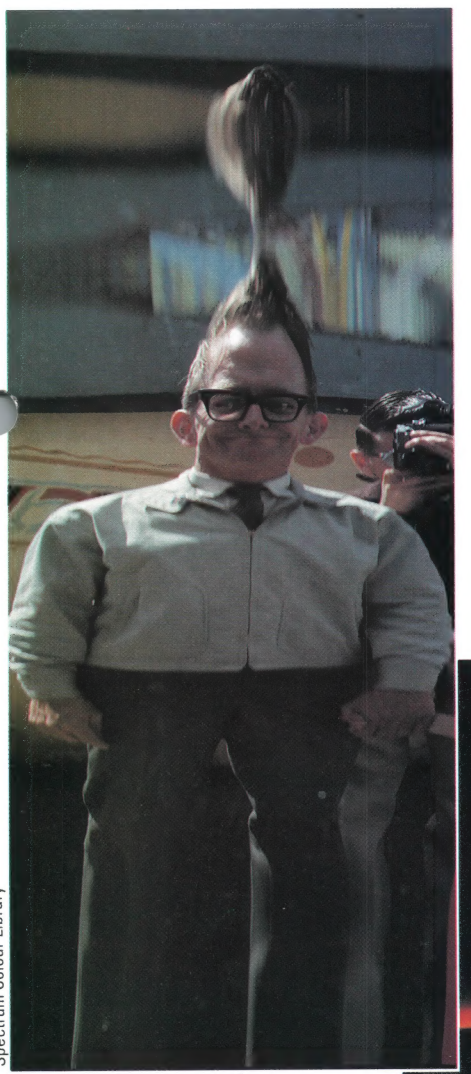
The images formed by curved mirrors are different, even though the same rules of reflection still apply. There are, in effect, two types of curved mirror: concave – where the reflecting surface is inwardly curved; and convex – where the reflecting surface is outwardly curved.

If the mirror is concave, the perceived image can be smaller, larger, or upside down or the right way up. The image you see in a concave magnifying shaving mirror is a larger, virtual image the right way up. The image produced at the focal point of a concave mirror used for astronomy is a real (that is, an image located in front of the mirror) upside down image. Its size depends on the focal length of the mirror.

If the mirror is convex, the image produced is always virtual and

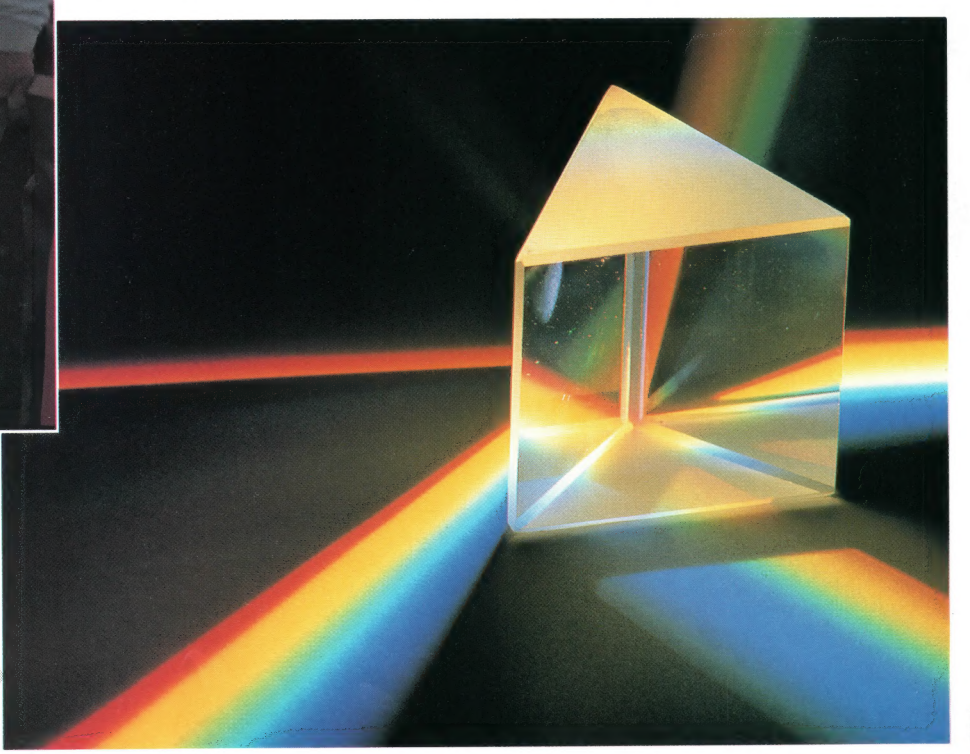
James A Bourdier/Colorific!

Sunlight *tans the skin – and can cause severe burning (inset below). Some rays penetrate deep into the skin and may cause skin cancers and premature aging.*



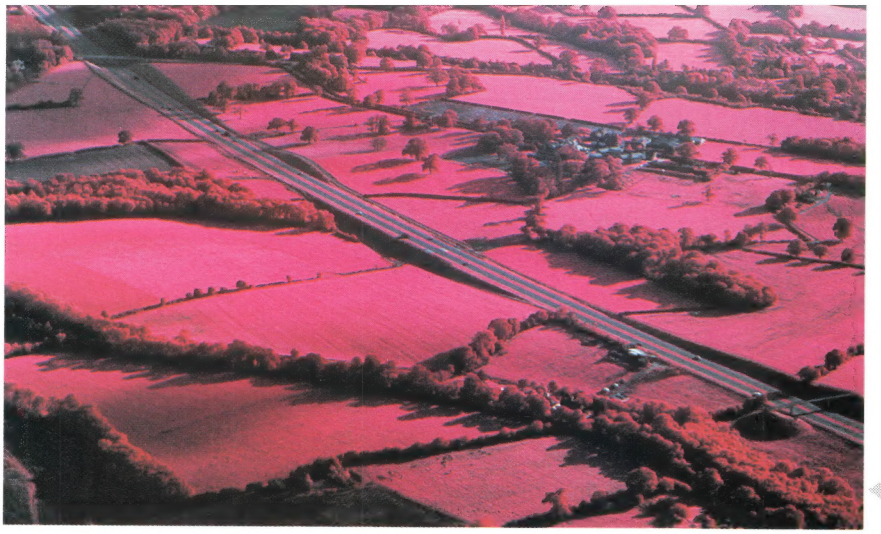
Spectrum Colour Library

Distorting mirrors *use an undulating (wavy) surface, alternately convex and concave, to produce weird, fun-fair effects.*



ZEFA

The dispersion of light *into its various component colours occurs when it is passed through a prism. Red light is refracted (bent) less than blue light, producing the familiar spectrum.*



Department of Defense; US Air Force

Infra-red equipment *can see in the dark – even when there is no light, heat is still given off, so areas of land become visible.*

smaller. This fact is very useful for rear-view car mirrors because smaller images allow a wider field of view.

Bending light

The speed of light in a vacuum is approximately 300,000 km/sec. It is slightly less in air, but is significantly less in denser materials such as glass or water. So if a ray of light strikes the boundary between air and glass at an angle, it changes direction and appears to bend. This phenomenon is called refraction.

When light passes through a flat sheet of glass it is refracted at the two air/glass boundaries by equal and opposite amounts. So it emerges parallel to the direction it entered. But when the sides of the glass sheet are not parallel, the effect is to change the direction of the light when it leaves the glass. So the path of light through a prism appears to bend at the surfaces.

Light of different wavelengths is refracted by differing amounts as it passes through a prism. This explains why a spectrum is produced when sunlight (made up of all the colours of the visible spectrum) is passed through a prism. The white light is split into its components: red, orange, yellow, green, blue, indigo and violet.

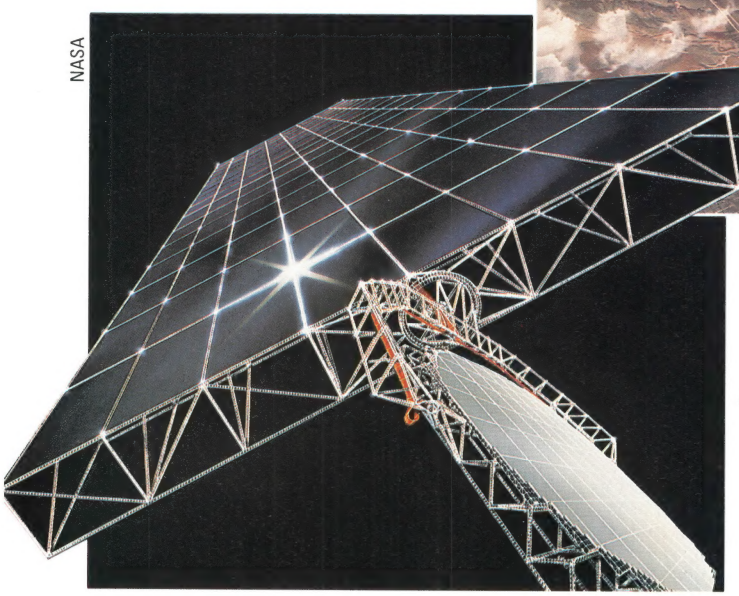
Refraction is exploited in lenses of various types. Again there are essentially two types of lens: converging and diverging lenses. In a converging lens the middle is thicker than the edges and in a diverging lens the edges are thicker than the middle.

A converging lens works in a way similar to two prisms placed one on top of the other, flat sides together. The light converges towards the centre of the lens and on leaving the lens can form an image. A diverging lens is like two prisms stacked point to point and the light diverges away from the centre.

Lenses can be used to magnify objects. The simplest form of enlarging lens is the magnifying glass, which forms a larger, virtual image of the object. This happens when the object is placed at a position close to the lens, inside the distance at which it would bring light from a distant object to a focus.

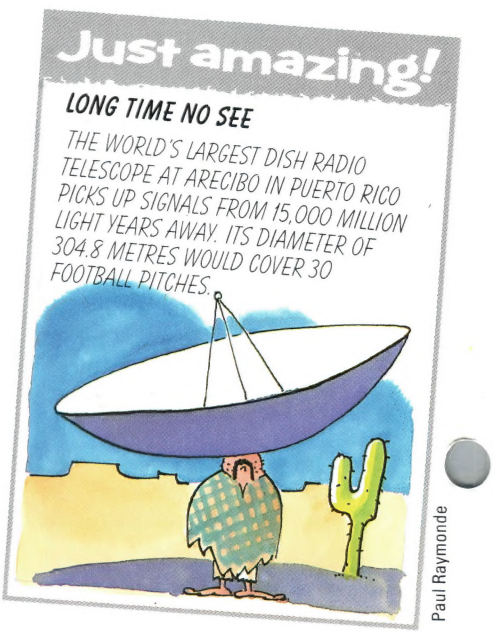
Because lenses are like prisms, light is split into different colours as it passes through them. This effect can cause fuzzy, out of focus falsely coloured images in cameras, telescopes or microscopes. To get round this, lenses with differing powers of dispersion are combined to bring the colours back together at the same point. The dispersion in one lens is corrected by the dispersion in the other. In a two piece achromatic (colour free) lens, crown and flint glass are most likely to be used.

NASA



NASA

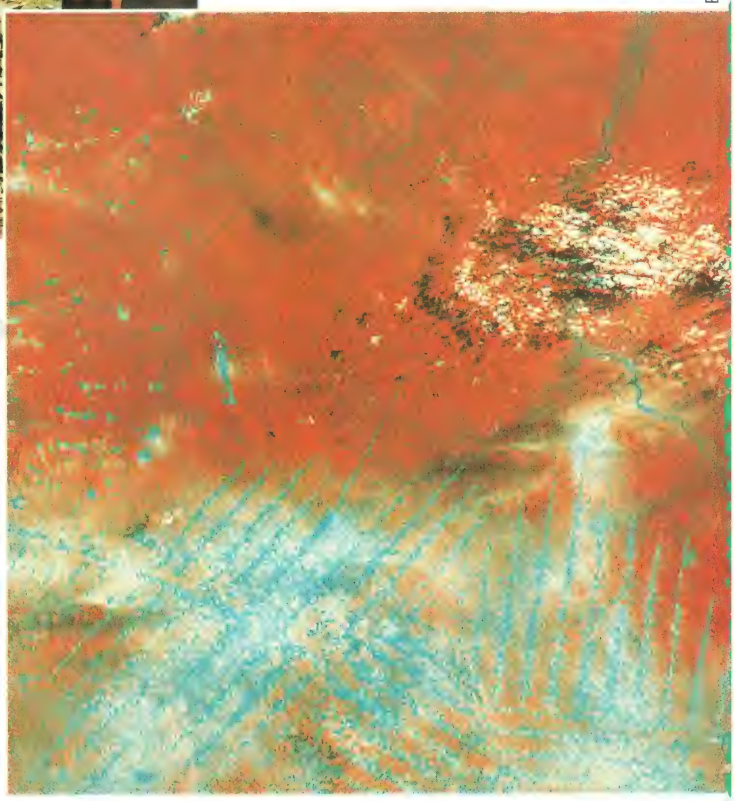
Massive satellites *would be needed to supply all the world's energy needs from space. They would weigh 50,000 tonnes and have a solar collector area of 50 sq km. They would beam 5,000 megawatts of energy back to a ground receptor (above).*



Paul Raymonde

Bernard Regent/Hutchison Library

- CROP ROTATION
- ASH FERTILIZER
- SOIL EROSION



Earth Satellite Corporation/S

FARMING THE JUNGLE

***Bananas** are just one of the crops produced from cultivated jungle areas. They are picked green and ripen in transit. Over one million tonnes of bananas are imported into Europe every year.*

***A false-colour** satellite picture of western Brazil shows vast areas of jungle (blue/white) that have been cleared by 'slash and burn' farmers. The red areas show healthy vegetation.*

THE US FAST-FOOD INDUSTRY is thought to have been responsible for the destruction of more than a quarter of Central American rain forest: it takes five square metres of rain forest to raise enough beef to make just one American hamburger.

Although about one-third of Costa Rica has been converted to pastureland, most of the beef is exported to the USA. The average Costa Rican eats less beef than the average American pet cat.

A more traditional method of farming in the jungle is 'slash-and-burn' cultivation or shifting agriculture. An area of forest is cleared, usually by slashing through the undergrowth and burning the trees. The ash from the burnt vegetation acts as a fertilizer and crops can be grown for two or three years.

Regeneration

Soil rapidly becomes worn out by this sort of farming and the people move on and clear a fresh area. The jungle takes 15 or more years to grow back, after which the land can be used again.

So long as the number of people farming this way remains relatively small, this method of agriculture works reasonably well. But if there are too many people in an area, old sites have to be reworked before the soil has had time to recover.

Overworking occurs particularly when highways are built through the forests and settlers move in to colonize the land. In one agricultural colonization experiment at Iata in the Amazon forest, the cleared fields became virtual rock pavements after less than five years.

Forest farmers

The Lancandon Maya of southern Mexico are expert farmers. They use the techniques of their ancestors to cultivate their forest plots in ways that mimic the plants in the natural forest.

They choose areas of ramon and ceiba trees that grow on rich, well-drained soils and burn the area to create a nutrient-rich ash. To prevent soil erosion, the Lancondon plant fast-growing trees such as banana and papaya to provide shade, and root crops such as taro to anchor the soil. A few weeks later, they plant their staple crop – maize – along with as many as 80 other fruits and vegetables.

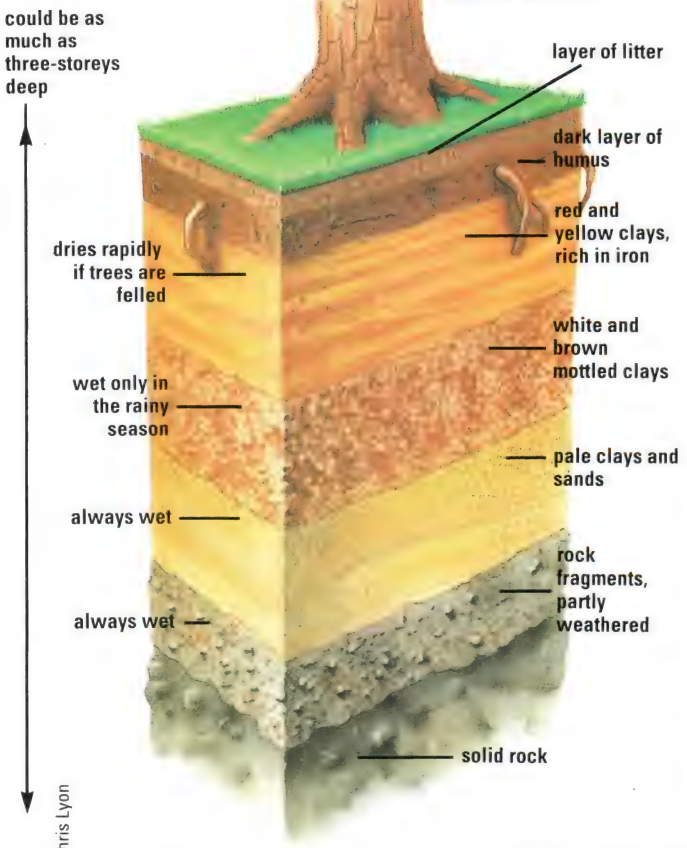
Planting times are decided by watching certain 'indicator' plants in the forest. This way they take account of annual variations in rainfall and temperature.

The crops are not planted in tidy rows. Instead, they are arranged in

***Ash deposits** from the burning of felled trees helps to replenish the soil with essential nutrients. Maize (right) grows well in the cleared areas – but only for a few seasons.*

Colin Jones/Impact Photos Hutchison Library

Soil Profile



Chris Lyon

Deforestation *allows the top two layers of soil – the litter layer and the dark humus – to be washed away. The exposed clay then hardens in the Sun.*

Scrawny cattle *are left to feed on the thin scrub that grows after a forest area has been cleared.*

Hutchison Library

vated peanuts to produce a strain that is resistant to a disease called leaf spot. It is estimated this improvement will save $500 million a year.

In rain forests, most of the nutrients are 'locked up' in the plants and trees, so the soil is generally poor. If the forest is removed, the frequent heavy rains wash the few nutrients out of the soil. This 'washing out' is called leaching. Fertilizers are very effective where there is sufficient crop plant cover. Even so, the uptake of nutrients is very slow. Some nutrients pass right through the soil as soon as they are dissolved by rain; others form insoluble compounds. When the jungle soil is cleared of trees, it is exposed to the Sun and oxygen and can turn into a hard, brick-like clay called laterite which, though useful for building, will not support plant life.

The international trade in just nine rainforest spices that are now commonplace in most kitchens – pepper, ginger, cloves, cinnamon, cassia, mace, nutmeg, allspice and cardomon – is worth well over $500 million. So rain-forest crops are extremely important to many Third World countries.

LOOK OUT – NUTS!

Brazil nuts grow on trees in the Amazon rain forests. About 20–30 nuts grow inside large coconut-like pods at the top of trees 30 metres tall. Each pod weighs up to 3 kg and there can be hundreds of pods on one tree.

Some are grown in plantations but they do not produce sufficient profit in one lifetime, so most are gathered from wild trees in the forest.

The pods are harvested when the wind shakes them loose and they drop to the ground. The falling pods can kill, so collectors carry wooden shields for protection. The pods are gathered in baskets and taken to a forest camp where they are cut open with a long knife called a *tercado*. Downriver, the nuts are shelled ready for export. Spoiled kernels and shells are used as fuel to power the shelling plant.

L C Marigo/Bruce Coleman Ltd

layers of carefully mixed combinations. This makes the best use of available nutrients in the soil and limits the spread of pests and diseases. There are no spaces between the crops and no land is wasted.

Fallow land

After three to seven years, when the weeds become too difficult to manage, the Lacandon leave the plot to 'rest' for five to 20 years. In the fallow plot, they plant trees such as rubber, citrus and cocoa and harvest from these and other wild plants. The fallow areas attract wild animals, which are hunted to provide valuable protein-rich meals.

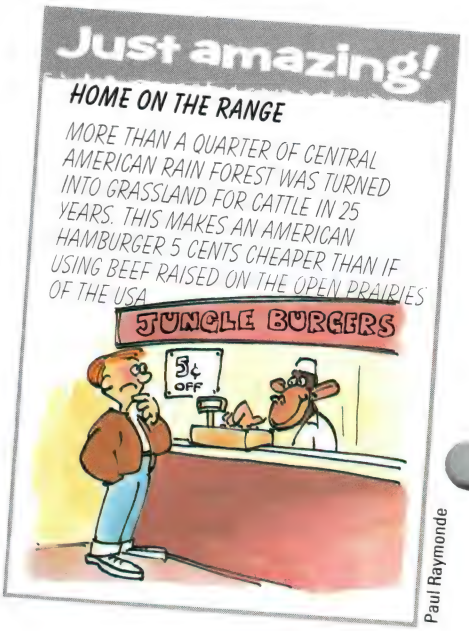
Unfortunately, only 20 per cent of the Lacandon still practise their traditional agriculture. The rest have been herded into government-controlled villages so that the forests can be colonized by settlers and cattle ranchers.

New food crops

Many of our foods including bananas, cocoa, coconuts, coffee, aubergines, lemons, oranges, papayas, peanuts, pineapples and tea originally came from the tropical rain forests.

Rain forests are still the potential source of many new crops. Generations of Indians in Paraguay have used the leaves of the stevia plant as a sweetener. Now Japanese chemists have analysed these and found that they are virtually calorie-free, harmless to humans and 300 times sweeter than sugar.

Breeders have crossed wild peanuts from Amazonia with culti-



Paul Raymonde

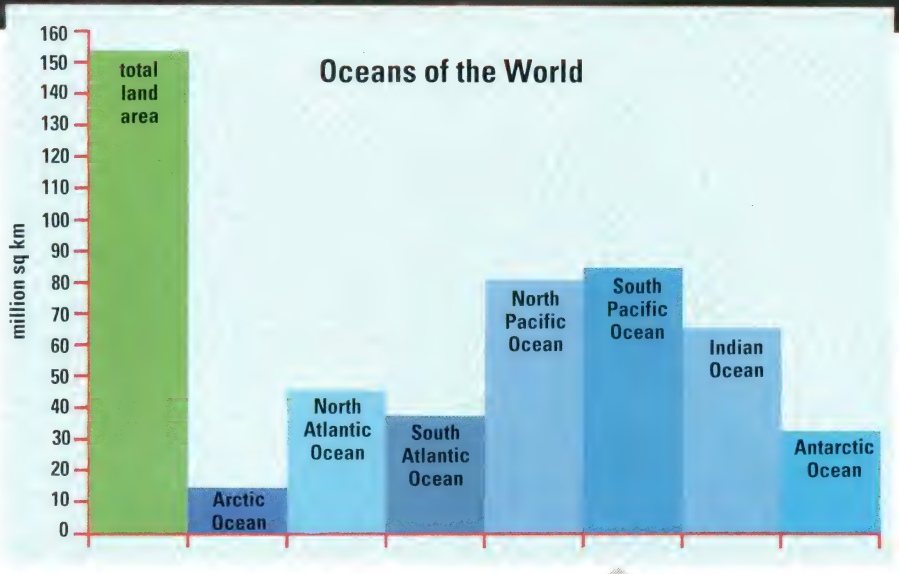
EXPLOITING SALT WATER

***The Dead Sea** in Israel is actually a salt lake with no outlet to the world's oceans. It is so salty that you can float on it with ease, reading a paper if you wish, but no fish can live in it.*

SEA OF MINERALS

SALT LAKES

DESALINATION



***The oceans** of the world together account for two thirds of its surface area. The boundary between the North and South Atlantic and Pacific Oceans is the equator.*

Caroline Brodie

THERE IS NO MORE VITAL resource than water. Yet, although the world has a vast supply, 97 per cent of it is sea water and is too salty for either human or industrial use.

The salts in the ocean are the result of over 2,000 million years of disintegration of volcanic rock from the Earth's surface. Rivers and rainwater constantly wash salty minerals from the land to the sea. Yet the sea does not become saltier and saltier. It has a remarkable self-regulating mechanism (involving the melting of the polar ice caps and evaporation) that has maintained its present composition for millions of years.

Little oceans

When changes in the drainage pattern and climate cut off lakes from the sea, they soon become salt lakes. Great Salt Lake in Utah, USA, is one example. Situated over 1,400 m above sea level, it never was part of the ocean. Isolated from the self-regulating mechanism, salts are filtered out of the surrounding mountains; evaporation prevents the lake from overflowing. Over a period of 100,000 years parts of it have become eight times as salty as the ocean.

Similarly, most of the world's other salt lakes, such as the Dead Sea, Caspian Sea and Aral Sea, have acquired their salt in this fashion, independently of the ocean. They represent oceans in miniature.

Water suitable for drinking should not contain more than 500 ppm (parts per million) of salt. Sea water typically contains 35,000 ppm of salt. So, where fresh water supplies are insufficient, the only alternative to transporting fresh water by pipeline or tanker is desalination. This is the process of converting sea water to water suitable for domestic or industrial use.

Flash distillation

There are various methods of desalination, but the most effective is known as flash distillation. This involves heating the sea water to a temperature of about 90°C and then injecting steam to raise it further to about 120°C. The hot water is then passed to a low-pressure chamber where it instantly boils in a process called 'flashing'. The resulting steam is then cooled and condenses into pure water.

Large flash distillation plants are usually situated in particularly dry areas near the sea. One near Tijuana, on the Mexican coast, produces 27 million litres of fresh water a day.

The major drawback with this type of desalination is cost. One

C Maddock/Planet Earth Pictures

A desalination plant *at Dubai, United Arab Emirates. Making fresh water from the sea is an extremely costly process, only carried out by rich nations.*

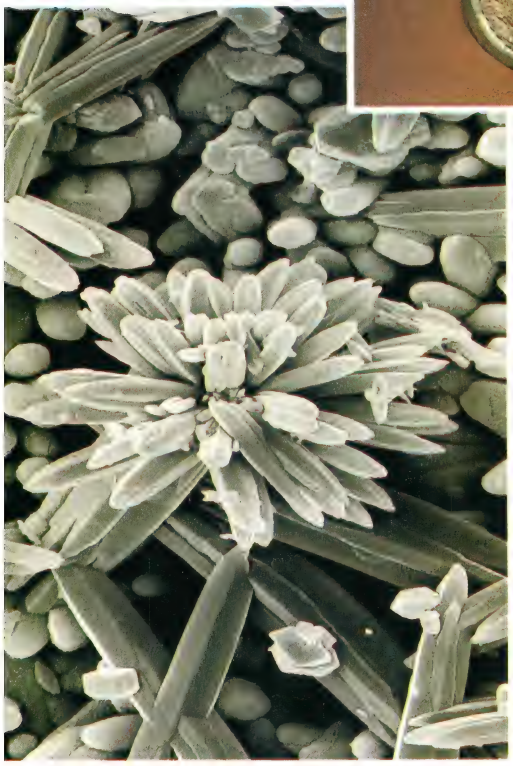
method of reducing the cost, favoured by Israel, is to employ the waste heat from a nuclear power plant to raise the sea water to the necessary temperature for flashing. Even so, flash distillation plants are only affordable by oil-rich nations such as Saudi Arabia and Libya and advanced ones, such as the USA. The need for fresh water, however, is so great that there are over 20 flash distillation plants currently operating and it is predicted that by the end of the century there will be at least 70.

The other main desalination process is electrodialysis. This involves using an electric current to separate fresh water from a salt solution. Electrodialysis plants with outputs of up to 2.25 million litres per day are commonly used to treat brackish water in the USA.

Cheaper and simpler but limited to sub-tropical regions is solar distillation. Several successful installations have been built on especially dry Greek islands, notably on Simi, near Rhodes.

Permutit Co Ltd

A photograph *through an electron microscope of 'fur' from a domestic kettle. This is formed from salt crystals found in hard water and can be dangerous in factory pipes (right), boilers and water containers.*



Dr Jeremy Burgess/SPL

Salt water crops

Over the last 20 years, agricultural scientists have done a great deal of work on the problems of irrigating with salt water. It has been found that not only can salt water be used successfully on sandy or gravelly soils but that some crops will happily accept a salt water diet. These include a dune grass, useful as animal fodder, a desert cactus, that can be used by the chemical and textile industries, and sugar beet.

Unusual, but not unique, is a rush (*Juncus maritimus*) that actually desalinates the soil in which it grows. When harvested, it produces pulp for the manufacture of high-grade paper.

THE NEED FOR SALT

Dan Smith/Allsport

There is no doubt among dietitians that too much salt is a bad thing. It is believed that the taste for salt, in the form of normal table salt (sodium chloride), sea salt (with additional iodide) or a salt substitute (potassium chloride) is a 'learned response' - you like it because it has always been added to your food, either in the cooking or at the table – often both. Excess salt in your diet can lead to an increase in blood pressure and can strain the kidneys.

The average person consumes 10g of salt per day yet your body needs no more than about 1g of salt a day. However a lack of salt, called salt depletion, can have dramatic effects. The first signs are cramp (the involuntary and painful bunching of muscles, normally in the calf), muscle spasms (sharp pain associated with sudden movement) and a slight rise in the pulse rate. Severe salt depletion – normally through sweat – will lead to a large fall in blood pressure, coma and death.

Just amazing!

NOT A DROP TO DRINK

IF ALL THE SEAS DRIED UP THERE'D BE ENOUGH SALT LEFT TO BUILD A WALL 280 KM HIGH AND 1½ KM THICK AROUND THE EQUATOR.

Paul Raymonde

THE WATER CYCLE

- ICE CRYSTALS
- FOSSIL WATER
- THE WATER TABLE

WATER IS BY FAR EARTH'S most abundant liquid, covering about three quarters of the Earth's surface.

About 97 per cent of the water is salt water in the oceans; the remaining three per cent is fresh water.

The amount of fresh water has been calculated to be more than 37 million cubic km – enough to fill the Mediterranean over ten times. Most of this fresh water is continually circulating in what is known as the water cycle.

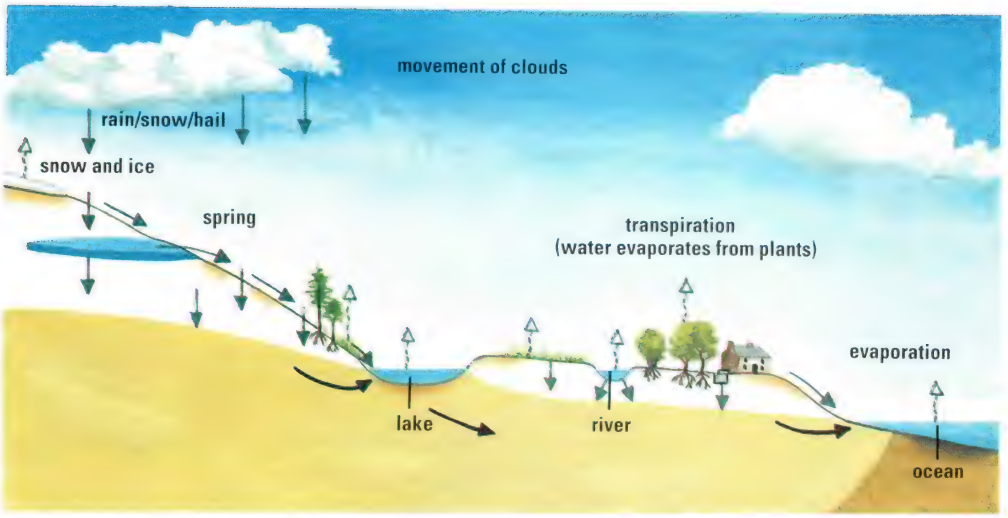
Water from the sea is taken up into the clouds. It falls from the clouds on to the land. Some of the water flows down into the sea again; some is taken up into the air directly; some drains into stores of water under the ground.

Power of the sun

The driving force behind the water cycle is the Sun. The heat of the Sun evaporates water from the oceans and the land. (Evaporation is the changing of liquid to vapour). Water evaporates into the air and

Rainfall is measured *as the depth of water that would have covered the ground if no water ran off into streams or drained into the soil*

Clouds*, made up of masses of tiny water droplets, above the Atlantic Ocean and the Cape Verde Islands off the west coast of Africa.*



Caroline Brodie

The water cycle *is the process whereby water evaporates into the air from the sea, rivers, lakes and the leaves of plants, and returns to the land (and sea) in the form of rain, snow or hail. Some of the rain drains underground and remains there, or seeps back into the oceans.*

forms clouds, leaving the solids – including the salt – dissolved in the water behind.

The clouds are blown by the wind from above the sea to above the land. In the clouds, in the cold of the upper air, vapour changes into droplets of water – each droplet forming around a tiny fragment of dust.

Droplets join together until they are too large and heavy to float on the air currents and they fall to the ground as rain. Sometimes droplets that are not yet heavy enough to fall are carried higher, where the air is even colder. Here, tiny frozen droplets – ice crystals – are formed, when vapour freezes around dust particles in the air – snowflakes are ice crystals joined together. Often, however, ice crystals melt on the way down and reach the ground as rain.

Hail is frozen raindrops. A frozen droplet is carried up again and again to the level of the atmosphere where water freezes. On each trip upward another layer of ice freezes on to the droplet, the droplet falls and then air currents buoy it up again. Eventually, the hailstone becomes so heavy it plummets to the ground, falling so fast it does not have time to thaw.

Some of the water that sinks into the ground is absorbed by plants, and then transpired into the air. Transpiration means the evaporation of water through pores on the undersides of leaves called stomata. These open during the day and close at night.

Transpiration

The rate of loss of water from the leaves depends on the intensity of light, the humidity (the amount of moisture in the air), the temperature and the strength of the wind.

In a desert, the rate of water loss from leaves is high because of the hot sunlight and the dry air. (Leaves have adapted by developing thick waxy surfaces that prevent as much water as possible escaping from the plant).

In contrast, the high rainfall and still air of the tropical rainforests ensure there is so much water vapour in the atmosphere around a transpiring leaf that very little water escapes from the stomata.

Water that is not absorbed by plants passes underground along cracks and crevices in rocks until it reaches a layer of rock through which it cannot pass. The water flows along the upper surface of this non-porous layer until it finds

Hans Christian Heap/Planet Earth Pictures

Water is scarce *in the desert because rainfall is low – less than 25 cm a year – and the rate of evaporation very high in the dry, hot climate. Day temperatures can rise to between 30 and 40°C.*

Lucy Horne/SPL

Tropical rainforests *are hot and humid, having at least 150 cm of rain each year. Evaporation is low because of the amount of water vapour already in the air.*

WIRTH GmbH

A drilling rig, *sinking an artesian well in Iran. The water gushes out under natural pressure, without being pumped.*

Mark Wagner/Aviation Picture Library

***Droplets freeze** on to the body of an aeroplane flying through clouds so high that the temperature is well below 0° C. The wings must be de-iced before the aeroplane flies again.*

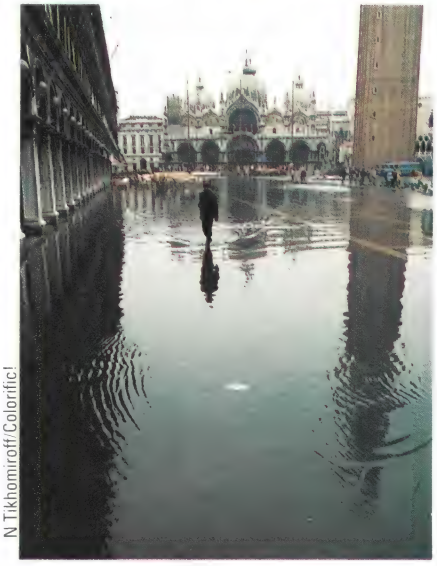
an outlet on to the surface of the land, where it flows out as a stream. Several streams join together to form a river which flows to the sea, continuing the cycle.

Water that does not escape on to the surface accumulates underground, where it is known as groundwater. The pores of the rock levels above the non-porous layer become filled with water. The top surface of this saturated layer is the water table. As the water at the base of the porous rock runs out, the water table lowers. If there is a drought, the water level also falls, because the amount of water percolating down from the surface has lessened.

Underground

A store of water below the surface is called an aquifer. Boreholes are drilled down to aquifers and the water brought to the surface and used for watering crops on desert and semi-desert land. Sometimes the water wells up under its own pressure, but as the level of water in the aquifer falls, the water has to be pumped up.

***A hailstone** is formed by layers of ice freezing on to a frozen raindrop. A cross-section reveals a structure like an onion. Stones usually fall in a short, heavy shower as part of a thunderstorm.*



N Tikhomiroff/Colorific!

***St Mark's Square** has been under water in floods. Venice has suffered, partly because of land subsidence caused by pumping up groundwater.*

Some aquifers have been in existance for a very long time. These stores of 'fossil water' are preserved between layers of impermeable rock. For example, below the Sahara desert are aquifers that originated in the last Ice Age and are up to 35,000 years old. Because rainfall is so low, in many areas this is the only source of water. Aquifers are slowly being drained, because the fossil water that is pumped to the surface cannot be replaced.

The 'centre-pivot' method of mining underground water is commonly used in southern and western regions of the USA, where there is not enough rain to grow crops. A borehole is sunk into the aquifer; water is pumped up and sprayed over the crops using a revolving boom hundreds of metres long.

However, this method uses up a great deal of water. Much more water is being taken out of aquifers than can pass in. In parts of Texas, the water table fell by more than 100 metres in the 1970s and 1980s. Water that has fallen as rain, draining through the soil and porous rock layers, only raises the level of the water table between one and 12 mm a year.

National Centre for Atmospheric Research/National Science Foundation

Fighting the sea

In an aquifer near the sea, below the top layer of fresh water is salt water. This has seeped in from stores of sea water in layers of porous rock beneath the sea. Re-

Just amazing!

KILLER STONES

GIANT HAILSTONES KILLED 92 PEOPLE IN BANGLADESH IN 1986. THE HAILSTONES, THE HEAVIEST ON RECORD, WEIGHED 1.02 KG EACH – OVER TWICE THE WEIGHT OF A FOOTBALL.

Paul Raymonde

PROFILE

THE WORLD'S LONGEST RIVERS

THE WORLD'S LONGEST RIVERS

River	Outlet	Length in kilometres	Average discharge of river into outlet in cubic metres a second
Nile	Mediterranean Sea	6,650	3,000
Amazon	South Atlantic Ocean	6,440	180,000
Chang Jiang	East China Sea	6,300	34,000
Mississippi	Gulf of Mexico	6,020	18,000
Yenisey	Kara Sea	5,540	19,000
Huang He	Gulf of Chihli	5,460	(no figure available)
Ob	Gulf of Ob	5,410	15,000
Parana	Rio de la Plata	4,880	22,000
Zaire	South Atlantic Ocean	4,670	41,000
Amur	Sea of Okhotsk	4,440	12,000

Townsend Dickinson/SPL

***Red spruce** in Vermont, USA killed by the increase in soil acidity due to acid rain. Smoke, fumes and exhaust gases have polluted the rain so that it is sometimes as acid as vinegar.*

David Jesse McChesney/Planet Earth Pictures

***Salt pan** on the floor of Death Valley, California. Rivers washed salts into a shallow lake on the valley floor. The salt was left behind when the lake evaporated.*

move the fresh water, and the salt water will rise to replace it.

This happened in the Tel Aviv area of Israel when intensive farming and new factories depleted local aquifers' supplies of fresh water. The water in them became more and more salty.

Israel solved the problem by bringing in fresh water from wetter, northern Israel along specially dug canals. It is poured into a line of wells along the coast, and down boreholes directly into the aquifers to raise the water table.

A similar problem is occurring in Spain where fresh water is being pumped up from aquifers to water tomatoes. In places, the water has become too salty to grow the tomatoes.

Another problem is land subsidence. As water is pumped out, the land settles, creating depressions. For example, during California's six-year drought which ended in 1992, farmers used so much ground water that the water table fell, causing land in parts of the Central Valley to subside by as much as nine metres.

Venice is sinking

Venice (built on 118 islands just off the coast of Italy) is sinking at the rate of 30 cm a century. A major reason for this is that aquifers are being emptied by electric pumping to supply factories at the port of Marghera on the mainland opposite the centre of the city. As the land subsided, the number of floods, and their severity, increased. The rate of use of groundwater is now strictly controlled. It is planned that, once canals have been built to bring water down from hills on the mainland, no water will be used from the aquifers.

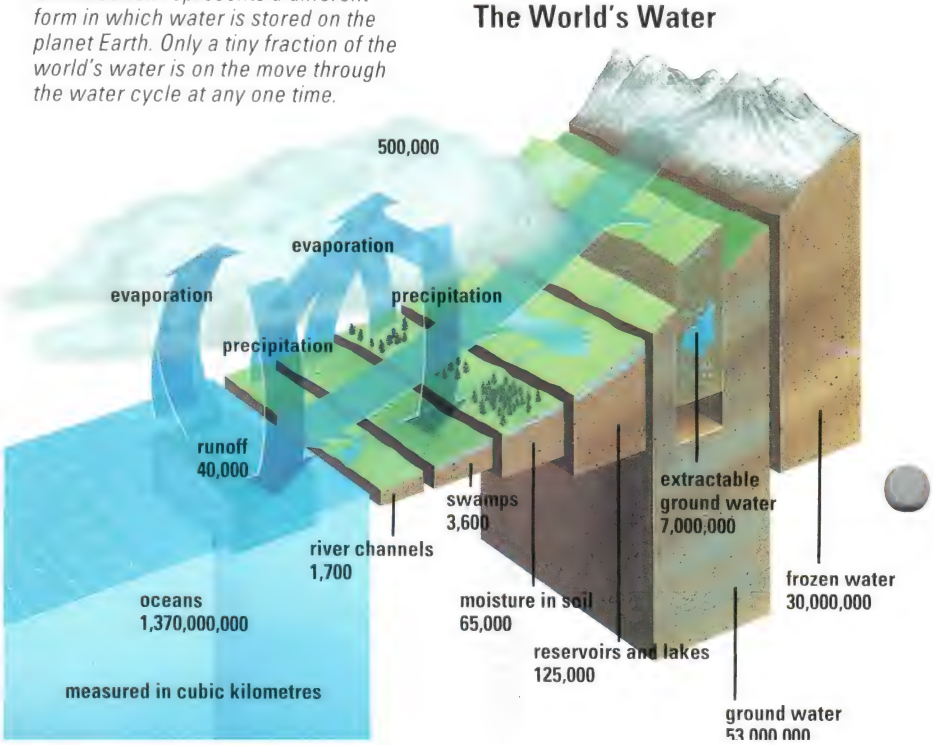
***Irrigation networks** are being improved in East Java, Indonesia, in order to increase crop yields, especially of rice. Instruction in the operation and maintenance of an irrigation scheme is essential.*

Mott MacDonald

Every year, the world's rivers carry 2,000 million tonnes of mineral salts down to the sea. Where artificial irrigation channels have been dug, mineral salts are held on the land instead – they are not washed downstream and away. As plants transpire and water evaporates into the atmosphere, salts in the water are left behind. They accumulate in the soil, until the soil becomes barren.

When it rains, some of these salts are washed through the soil and into the groundwater. The groundwater eventually becomes so salty that the soil becomes infertile and no crops can be grown.

***Each section** represents a different form in which water is stored on the planet Earth. Only a tiny fraction of the world's water is on the move through the water cycle at any one time.*



Steve Cross

SOUND VIBRATIONS

- SOUND ENERGY
- MUSICAL NOTES
- ULTRASOUND

SOUND IS A FORM OF ENERGY. It is vital to our understanding of the world because we communicate so much through sound, and the world is full of sound – doorbells ringing, records playing, and people talking.

Sound energy is produced when an object vibrates. The vibration sets the surrounding air in motion and the air carries the vibration as waves – it is these sound waves that we pick up with our ears and interpret in our brains; that is when we hear the waves as sound.

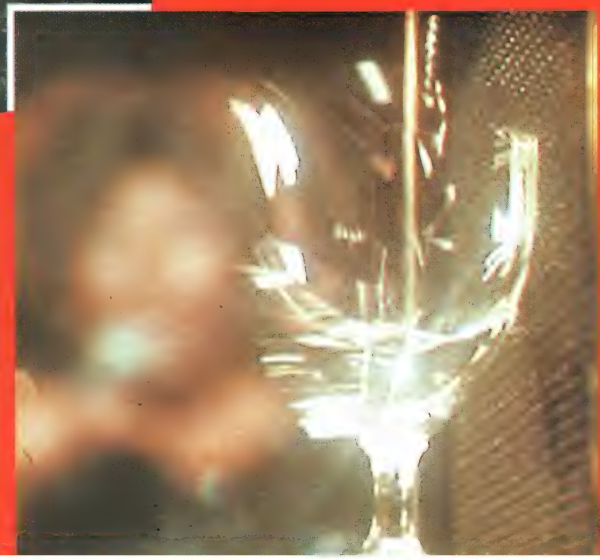
Tony Stone Photo Library, London

Silent vacuum

Think of air as a liquid and the sound waves as ripples and you will understand why there can be no sound inside a vacuum – because there is no air.

Some vibrations are over very quickly, while others last much longer. When you clap your hands the vibration doesn't last very long – it is little more than a shock wave in the air. But you can make a sound which lasts much longer. Put a ruler on the edge of a table, hold down one end, and ping the other end. You can see and hear the ruler vibrating for a few seconds. When you speak, it is the vibration of your vocal cords that makes the sound. If you put your finger on the 'Adam's apple' of your throat as you speak you can feel your vocal chords vibrating with the sound.

The sound of the ruler is a sort of rattling hum. But a tuning fork makes a much purer ringing tone when struck. This is because the sound waves from the tuning fork are more regular and smooth. The more even and regular the vibration of the sound, the nearer it gets to being a musical note.



Memtek Products

Shattering glass *with her voice, jazz singer Ella Fitzgerald can hit such pure notes that they act like a beam of ultrasound. The molecular structure of the glass vibrates to such an extent that it breaks up and the glass shatters. The effect was used in an advert for cassette tapes, where the manufacturer claimed that their reproduction was so pure that even a recording of Ella shattered the glass.*

Sine waves

Sound waves produced by the tuning fork are much more regular than the sound waves produced by a door shutting, for example. The regular wave made by a tuning fork is known as a sine wave.

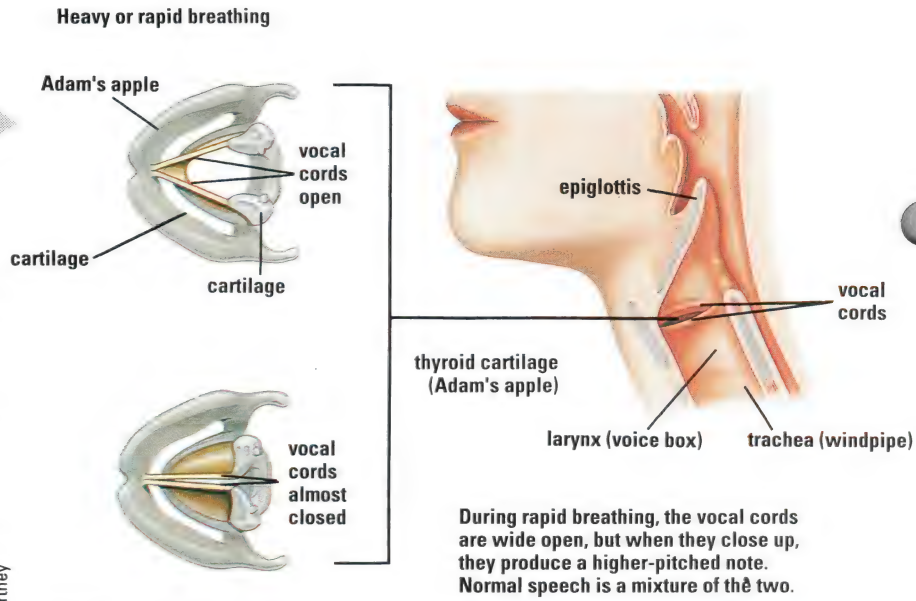
Not many sounds occur as pure sine waves – only pure musical notes. Most sound waves are much more complex.

Pitch and volume

The more frequently the air is compressed, the higher the pitch of the sound, and the more air particles are compressed, the louder the volume.

Sound travels at about 340m/sec at sea level, but light travels almost a million times faster – which is why you see lightning before you hear thunder during a storm.

Vocal cords *are two strong bands of tissue inside the larynx which vibrate as air from the lungs passes through. The effect is similar to the way the reed produces the sound in woodwind instruments.*



Mike Courtney

Some aircraft, such as Concorde, travel faster than the speed of sound. As it approaches the speed of sound, it begins to catch up with its own sound waves. As it overtakes them, it breaks the sound barrier, causing a shock wave – the sonic boom.

The Doppler effect

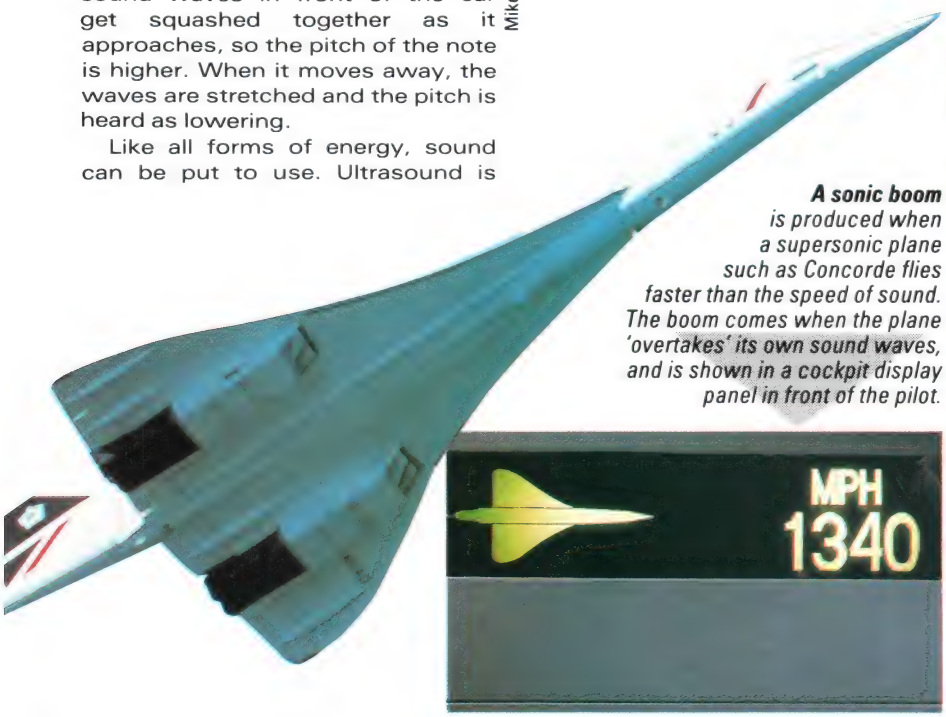
When a police car passes you with its siren going, the tone sounds higher as the car approaches than it does as the car speeds away. This is known as the Doppler effect. The sound waves in front of the car get squashed together as it approaches, so the pitch of the note is higher. When it moves away, the waves are stretched and the pitch is heard as lowering.

Like all forms of energy, sound can be put to use. Ultrasound is extremely high pitched – much too high for us to hear – and spreads out much less than low-pitched sound. It can be transmitted in a very tight beam, and the echoes which reflect back can be changed into electrical impulses to give a picture of the object that is reflecting the sound. Ultrasound can be used to produce a picture of hidden objects. For example, ultrasound can locate wrecks on the sea bed and shoals of fish, and doctors use ultrasound to check the developing baby inside a pregnant woman.

Ultrasound beams are also used by physiotherapists in the treatment of damage to muscles and joints. The waves of sound 'massage' the soft tissues, which aids healing.

ZEFA

A sonic boom *is produced when a supersonic plane such as Concorde flies faster than the speed of sound. The boom comes when the plane 'overtakes' its own sound waves, and is shown in a cockpit display panel in front of the pilot.*



British Airways

DRUMBEATS

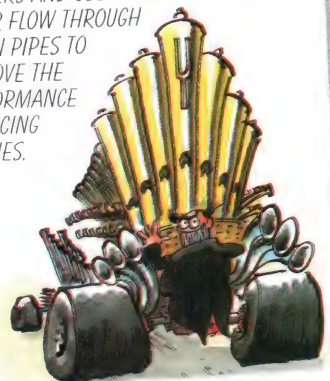
The beat of a drum shows how sound waves are made in the air. When you hit a drum the skin first goes down very quickly. It returns to its original position again but because it is elastic it bounces past the original position and keeps going until once again it reaches the limit of its elasticity. Then down it goes again.

The drumskin keeps going up and down until all the energy of the original strike is used up and it rests at its original position. All the time it has been vibrating up and down you have been hearing the beat, which goes on for a few moments after the drum is struck. Every time the skin goes up it compresses – squashes together – the air particles, and in between the waves of compression are waves where the air particles are 'stretched out'. It is these compressions and stretches that form the sound waves you hear.

Just amazing!

FINELY TUNED

YAMAHA – THE MOTORBIKE MANUFACTURERS – ARE ALSO ORGAN BUILDERS AND USE THEIR KNOWLEDGE OF AIR FLOW THROUGH ORGAN PIPES TO IMPROVE THE PERFORMANCE OF RACING ENGINES.



Paul Raymonde

Auto tuners *are often used for quick tuning. The guitar is plugged in, and digital LEDs show when each string is at the right pitch. The letters C D E F G A & B represent musical notes, and the numbers above them are the strings of the guitar.*

Hattori (UK) Ltd

AQUACULTURE

***Salmon** reared in man-made ponds can be fed well, protected from predators – and caught much more easily.*

Labat/Jerrican

***In the hatcheries,** fish eggs are stripped from the mother. They are incubated in conditions that ensure nearly every baby salmon survives.*

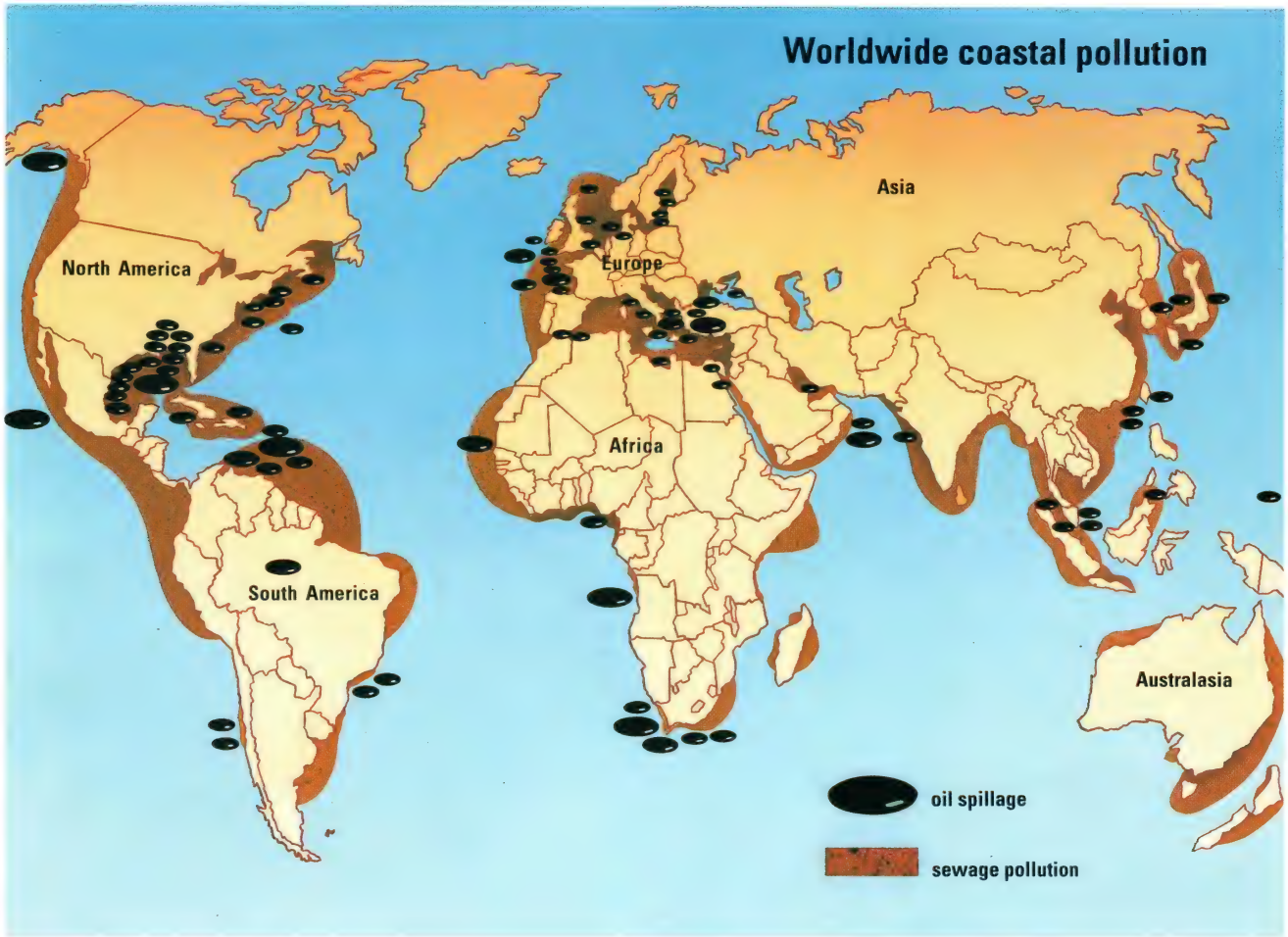
THE SEA CAN BE FARMED, just as the land can and fishermen – the 'farmers' of the sea – experience many of the same problems as their land-based counterparts: overproduction, pollution and the search for new crops.

There is nothing new in farming the sea, of course. For thousands of years people have caught fish and harvested seaweed – or kelp – for food and other purposes. Shark skin makes excellent sandpaper, while the rough scales of the strange coelacanth, a 'living fossil' fish from south-east African waters, are used by local people to roughen their bicycle inner tubes before sticking on a puncture patch!

On the shelf

Much of the fish we usually eat come from the relatively shallow waters over the continental shelf. Only a few hundred metres deep at most. The continental shelf surrounds the main continents. In volume, the seas there make up less than ten per cent of the water in the oceans. Yet 95 per cent of the

Keith Gunnar/Bruce Coleman Ltd



Joe Lawrence

***Industrial waste** and sewage pollute much of the world's coast lines. Oil-spills take their toll on both coastal waters and the deep ocean.*

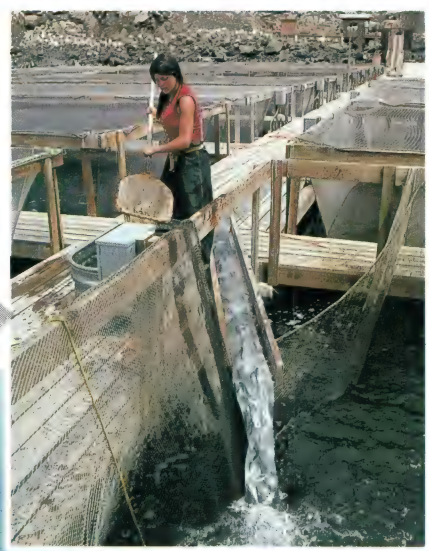
sea fish we consume comes from the continental shelf. In future, could the deeper parts of the oceans yield new kinds of fish to have with our chips?

Some countries are already exploiting the deep. New Zealand fishermen are trawling for a deep-sea fish called the orange roughie This creature is 50 cm long and orange in colour, with spiny fins and a wide mouth. Trawlers can catch up to 50 tonnes of orange roughie an hour. Since 1980, over 40,000 tonnes of orange roughy have been caught. This fish is important not only for its flesh, which is tasty, but for the waxy oil in its swimbladder, bones and other parts of its body. Orange roughie oil can be used in cosmetics to replace oil from endangered sperm whales. It is a good lubricant and can also be incorporated into textiles and polishes.

Rat-tails

One disadvantage of trawling at depths of over 1,000 metres is that it takes much longer to lower and raise the net, so fewer can be made each day. Another problem with deep-sea fish is their often strange appearance and peculiar names — both of which can be distinctly off-putting. For example, Soviet fishermen catch about 7,000 tonnes each year of a deep-sea fish we call the blunt-nosed rat-tail. It is difficult to imagine eager customers asking for 'rat-tail and chips' at their local chippy.

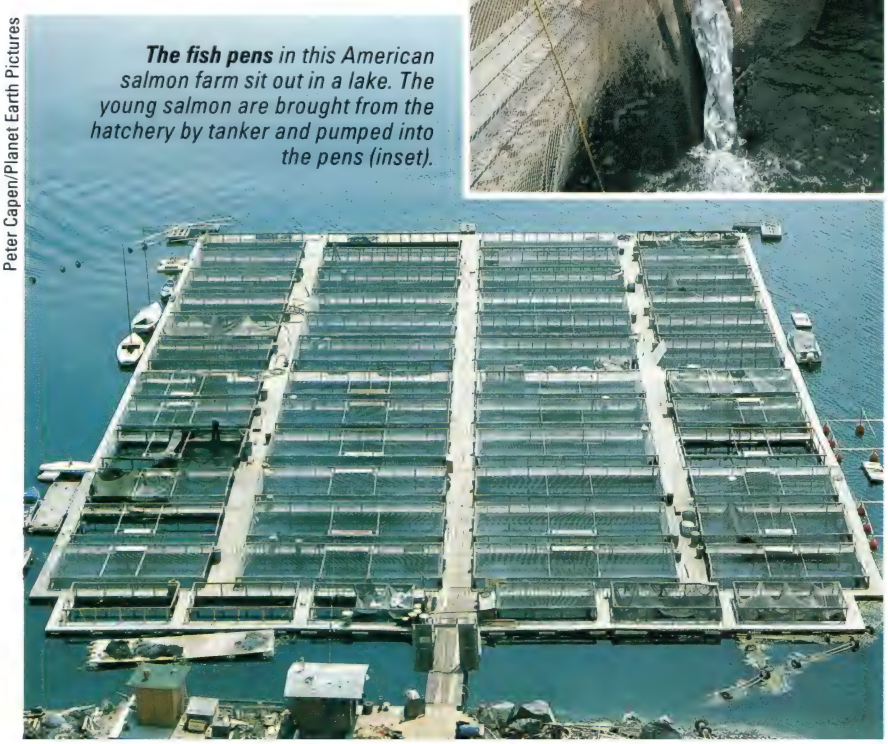
Meanwhile, fish farming, or aquaculture, is rapidly expanding. Scotland's salmon farms produced 2,000 tonnes of fish in 1970 and



Peter Capen/Planet Earth Pictures

***The fish pens** in this American salmon farm sit out in a lake. The young salmon are brought from the hatchery by tanker and pumped into the pens (inset).*

Peter Capen/Planet Earth Pictures



MISMANAGING THE SEA

Our seas are being fished out. Huge trawlers use sonar equipment to find shoals and vast nets to scoop them up, 'hoovering' the sea bed clean.

In 1965, 250,000 tonnes of haddock were caught in the north-west Atlantic. Just 10 years later, the catch was less than one-tenth of this. In the Pacific, the anchovy catch plummeted from 12 million tonnes in 1971 to two million tonnes a few years later. The story has been the same the world over.

The seas are also filling up with our chemical wastes. More than four-fifths of polluting chemicals in the sea come from land, flowing out along rivers. On average, six million tonnes of oil enter the sea each year. We may hear about accidental oil spills from tankers, but more than half of the annual oil pollution is washed down the rivers. Dangerous heavy-metal chemicals (such as mercury) now occur in the sea at many times their natural levels.

Liaison/Frank Spooner Pictures

Robert Jureit/Planet Earth Pictures

nearly 30,000 tonnes by 1990. Norway raises even more salmon. Iceland, Canada, Chile and Ireland are also developing their salmon-farming industries.

In Scotland, most of the suitable sites are now fully occupied by fish. So scientists are looking at the possibility of keeping salmon in huge cages out at sea.

Bad weather

The test cages are 25 metres across and hold about 40,000 young salmon, which are called smoults. The cages float mostly submerged. A computer-controlled hopper contains three tonnes of food, enough to feed the fish if farmers cannot reach them for a few days due to bad weather.

Sensors in the cage monitor conditions and send signals along a cable to shore, while video cameras record the salmon's movements.

Unfortunately, fish cages in lakes or near the coast create problems. As well as interfering with pleasure craft and water-users, the fishes' waste tends to build up, as there are no strong currents to sweep it away.

Offshore cages, with good water circulation, should not suffer from these problems. On the other hand, the cages' meshwork might become encrusted with weeds and marine animals. Also a big storm could rip them open and set the salmon free.

ZEFA

***Oysters beds** have been farmed in Japan for 300 years. Oysters need protection from strong currents (inset).*

In addition, the flesh of caged salmon is not rosy pink, like that of wild salmon, but 'hatchery grey'. To counteract this, some farmers add a synthetic colouring called canthaxanthin (E161g) to their fish feed. However, this additive is banned in the USA.

Turtle ranch

Sole and plaice farms have been built to take advantage of the warm water discharged from coastal power stations. In the Cayman islands, there is a turtle ranch. This was begun in an attempt to save the green turtle from extinction. But turtles are so productive, when their young are protected from natural predators, that the ranch now sells off turtles to make soup.

Oysters, shrimp and lobsters are all farmed and abalone – renowned as the 'filet mignon of the sea' because of its delicious steak-like

Just amazing!

PEARLS BEFORE SWINE

TOMMY GREENE OF ANNAPOLIS, MARYLAND, SWALLOWED 288 RAW OYSTERS IN 1 MINUTE 33 SECONDS.

Paul Raymond

***These ugly fish** may soon be accompanying your chips. The Viper fish and the Anglerfish (right) are nutritious and plentiful in the ocean depths, but they don't look very appetizing.*

Peter Parks/Oxford Scientific Films

D Parer & E Parer-Cool/Ardea

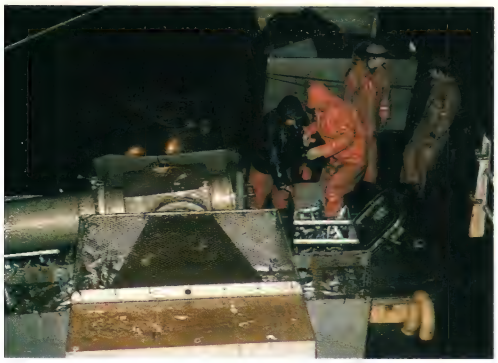
quality – is cultivated in under-sea shelters.

Around the world, fish farming produces about 15 per cent of all fish eaten. The industry is growing at more than five per cent each year. But compared to farming on dry land, it is still in its infancy.

Fish farms

Fish farmers now want to do with fish what land-based farmers did with cows and sheep centuries ago – breed them selectively to produce bigger, more docile, more productive 'domestic' strains. In Norway, in a huge research programme, scientists selected various strains of fast-growing salmon and inter-bred them. Over three generations, the salmon's growth rate went up 12 per cent in each generation.

But there have been few other successes. This is partly because fish growth, and the eventual size of an individual fish, seem to depend on so many factors. These include how aggressive the fish is at getting food, its resistance to disease, how much food is available and how crowded its pond is.



J Duncan/Planet Earth Pictures

***Huge modern trawlers** use massive pumps to almost literally 'hoover' fish off the sea floor, leaving little living behind.*

TUNA – BLOODED, BOILED AND TINNED

Jesus Perez/Planet Earth Pictures

Jesus Perez/Planet Earth Pictures

Tuna is one of the world's favourite fish. The Japanese – who eat it raw as sashimi – take around 60 per cent of the world's catch by stringing miles of baited hooks out behind their boats.

Here, Spanish fishermen use an older, more bloodthirsty technique. Boats surround a shoal, string a net under them and haul it up until the sea is a frothing mass of thrashing fish. The trapped tuna are then bludgeoned with boat hooks.

If a researcher or farmer wants to set up detailed breeding experiments, he must be able to identify individual fish. Notching fins, spotting fish with dye and branding their scales have all been tried.

A newer method involves a tiny electronic device called a transponder which is injected into the fish's belly. When the transponder is set off by waving a special 'magnetic wand' nearby, it sends out a 10-digit coded signal.

Fish farmers would like to breed fish that could convert their food to flesh more efficiently, that could survive in water that is more crowded and, thus, has less oxygen, and that are easy to catch and process.

Genetic engineers have been experimenting on fish in recent years. Although fish eggs are quite large when compared to eggs of mammals, the nucleus (the central part where the genes are) is very small. This makes it difficult for the technician to inject genes directly into the nucleus, so adding genes to a fish egg is a very hit-and-miss business. However at Auburn University, Alabama, USA, genes for growth hormone have been added to carp eggs. The resulting fish grew 20 per cent more quickly.

Anti-freeze

Some fish, such as the winter flounder, have 'anti-freeze' in their body fluids. This means they can withstand extremely low temperatures. Salmon in farm cages sometimes freeze to death because they lack that anti-freeze. So scientists are researching whether the flounder's anti-freeze gene could be added to the salmon to help it survive the extreme cold.

Fish Eagle Co

***Fish tagging** is important for researchers and farmers – only if individual fish are marked can they check on growth. This visible tag is inserted into the transparent tissue around the eye using a syringe or tweezers. Manufacturers claim only five per cent fell out.*

ANTIBIOTICS

ALTERNATIVE HEALING

ACUPUNCTURE

HEALING FORCES

HEALING IS THE MAGICAL process by which the body recovers from illness or injury. Often our minds and bodies work together to repair themselves naturally. But sometimes healing needs to be helped by one of many different forms of medicine.

Medicines used to stop pain, such as Aspirin and Paracetamol, are called analgesics. Analgesics do not cure diseases, but merely suppress the symptoms.

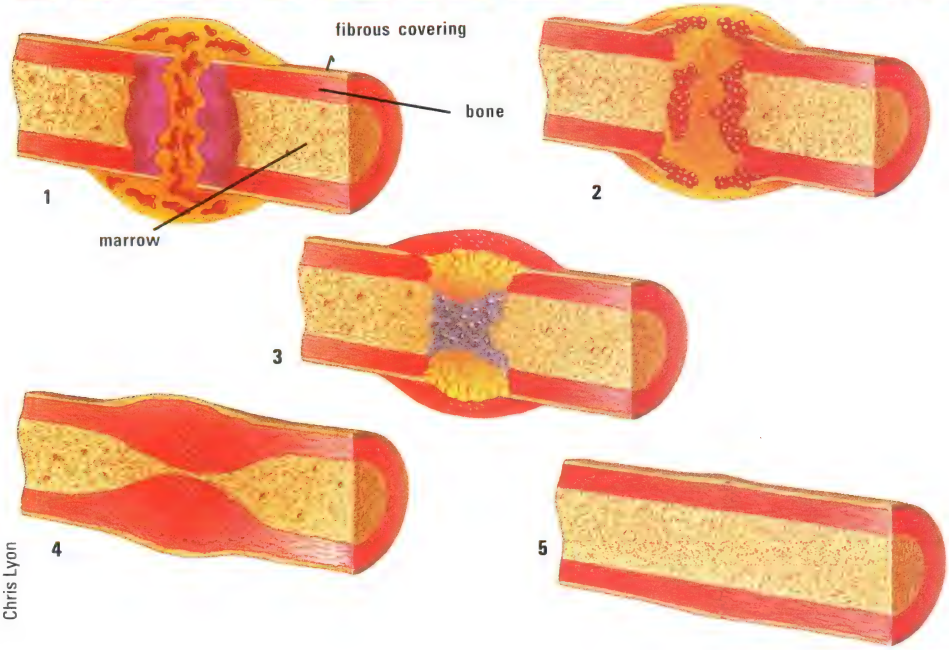
Drug side-effects

Antibiotics form another important group of medicines, which kill off the bacteria that cause some illnesses. They work by altering either the metabolism or cell walls of the bacteria. Penicillin is a widely used antibiotic which is derived from a type of mould and was discovered by Sir Alexander Fleming in 1928.

But one problem that many people find with taking drugs to fight illness is that they suffer from allergic reactions or adverse side-effects. This is why more attention is being directed towards alternative forms of medicine, such as osteopathy, chiropractic, naturopathy, homeopathy, acupuncture and herbalism.

Bacteria under attack. *These bacteria, which cause boils and abscesses, are being destroyed by antibiotics. The antibiotics break down the cell walls, causing the bacteria to fragment (top).*

CNRI/SPL



Chris Lyon

When a bone breaks, *the blood vessels running through it break too, causing bleeding and swelling. But it is the clotting of the blood which forms the 'scaffolding' for the repair of the bone (1). After about one week, bone cells from the broken ends start to spread into the clotted area, or callus (2). After three weeks, bone cells help form fibrous tissue, which unites the two ends (3). Later on, the finished join has a mass of bone around the site of the break and is still slightly swollen (4). After several months, the bone will smooth itself out, so that it returns to its original thickness (5). The break can then only be detected by X-rays.*

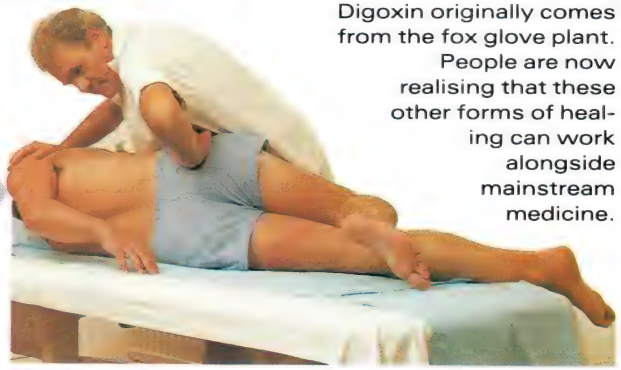
Adam Hart-Davis/SPL

Herbalism *is one alternative to the use of modern drugs (right). Many people suffer from side-effects or allergies when treated with modern medicines and they may find relief with herbal cures. But, in fact, many drugs are originally derived from herbal extracts.*

to scarlet fever. But homoeopathic doctors see the flush as a sign that the body's defence is working. So to fight scarlet fever, they would administer tiny doses of deadly nightshade extract and leave the body to cure itself. It was also discovered that the more the active substance is diluted, the more effective the homoeopathic remedy becomes. This is opposite to orthodox medicine where a stronger dose produces a stronger effect. So although some homoeopathic preparations can be poisonous in large doses, they are prescribed in such minute amounts that they are completely harmless.

Ancient and modern

Herbalism uses herbs to treat disease, often in the same way as drugs. The combinations of herbs have been passed down from generation to generation and were originally the result of trial and error. Many modern drugs have their origins in herbal medicine. For example, the active part of the heart drug Digoxin originally comes from the fox glove plant. People are now realising that these other forms of healing can work alongside mainstream medicine.



ZEFA

Osteopaths *treat their patients by manipulating the spine, joints and muscles. Although it looks painful, this form of treatment is highly effective – particularly for back problems. It is based on the principle that some injuries are caused by impaired blood flow or cramped nerves.*

Osteopathy aims to relieve aches and pains by manipulating the body, especially the spine, joints and muscles. Its founder, Andrew Still, believed that many illnesses were caused by impaired nerve and blood-flow, because the spine was out of place. Osteopaths must undergo several years full-time training at an approved college before they are registered.

Chiropractic is similar to osteopathy but is based on misplaced vertebrae disrupting the nervous system, and some of the manipulative techniques are different. Naturopathy is concerned with an holistic approach. This means looking at the body as a whole rather than specific symptoms. A naturopath believes in the body's innate ability to heal itself and will concentrate on the patient's lifestyle and diet. Often, a medicine-free regime is formulated, based on changes in diet, vitamin and mineral supplements. Hydrotherapy (treatment by hot and/or cold water) may also be used.

Like heals like

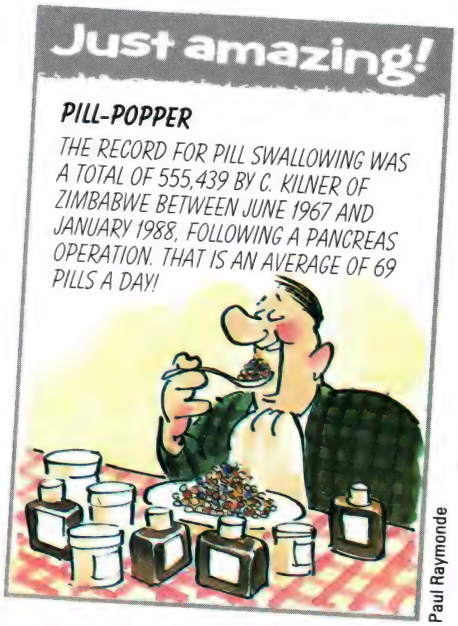
In homoeopathy, the idea is to stimulate the body's natural defences against disease by promoting a mild form of the disease. To do this, small doses of 'natural' drugs are administered. For example, the deadly nightshade berry is poisonous, producing a red flush similar to scarlet fever. But homoeopathic doctors see the flush as a sign that the body's defence is working. So to fight scarlet fever, they would administer tiny doses of deadly nightshade extract and leave the body to cure itself. It was also discovered that the more the active substance is diluted, the more effective the homoeopathic remedy becomes. This is opposite to orthodox medicine where a stronger dose produces a stronger effect. So although some homoeopathic preparations can be poisonous in large doses, they are prescribed in such minute amounts that they are completely harmless.

In the future, they may be incorporated in the health service. This would prevent much patient suffering and save a lot of money, which could then be channelled into research for the prevention of diseases.

CHINESE MEDICINE

Paul Biddle & Tim Malyon/SPL

Acupuncture is based on an ancient Chinese form of treatment, which uses, among other things, needles inserted into the skin to cure illness and injury. (This woman is being treated for headaches.) The ancient Chinese believed that energy flowed along channels called meridian lines in the body and that needles could be used to release blockages on these lines. A modern version is that the meridians correspond to the branches of the nervous system. Because the meridians run the length of the body, the acupuncture points may be far from the affected area. Acupuncture can also be used sometimes as a form of anaesthetic for operations.



Paul Raymonde

SUPER CIRCUITS

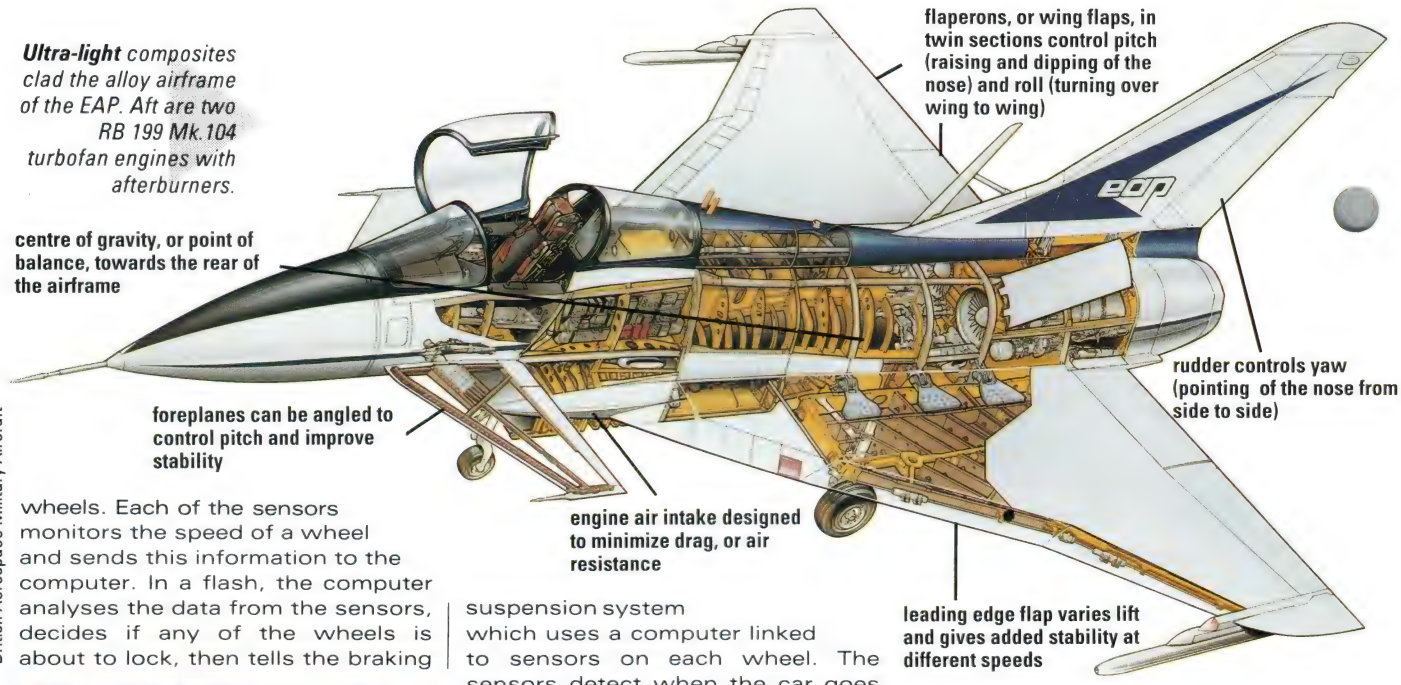
- NAVIGATION
- SAFETY FEATURES
- AUTOMATIC CONTROL

NOWADAYS COMPUTERS ARE revolutionizing every mode of transportation – from the cars, ships and planes that traverse the Earth to robot spacecraft that fly to distant planets. As in every other sphere of life, the magic of the microchip is endowing vehicles with intelligence.

Imagine a car in the dead of winter, speeding along a country lane splattered with sheets of black ice. Suddenly, a child darts out into the road ahead. The driver slams on the brakes. Surely catastrophe, but no – the car stops quickly and safely. The reason is anti-lock brakes.

Anti-lock computers are linked to four electronic sensors behind the

***The Euro Fighter** built by a group of West European countries, is designed to be unstable so it responds rapidly to the computerized fly-by-wire signals that control it.*



Ultra-light *composites clad the alloy airframe of the EAP. Aft are two RB 199 Mk.104 turbofan engines with afterburners.*

British Aerospace Military Aircraft

wheels. Each of the sensors monitors the speed of a wheel and sends this information to the computer. In a flash, the computer analyses the data from the sensors, decides if any of the wheels is about to lock, then tells the braking system to briefly release the wheel.

The computer does what every driver ought to do on a slippery road – it applies and releases the brakes rapidly to avoid a skid. The difference is that the computer can be relied on to do it perfectly every time – and up to ten times a second.

The British sports-car manufacturer, Lotus, is testing an active suspension system which uses a computer linked to sensors on each wheel. The sensors detect when the car goes over bumps in the road and send signals to the computer, which works out how much to soften the suspension. It all happens so quickly that the passengers are totally unaware of any roughness in the road.

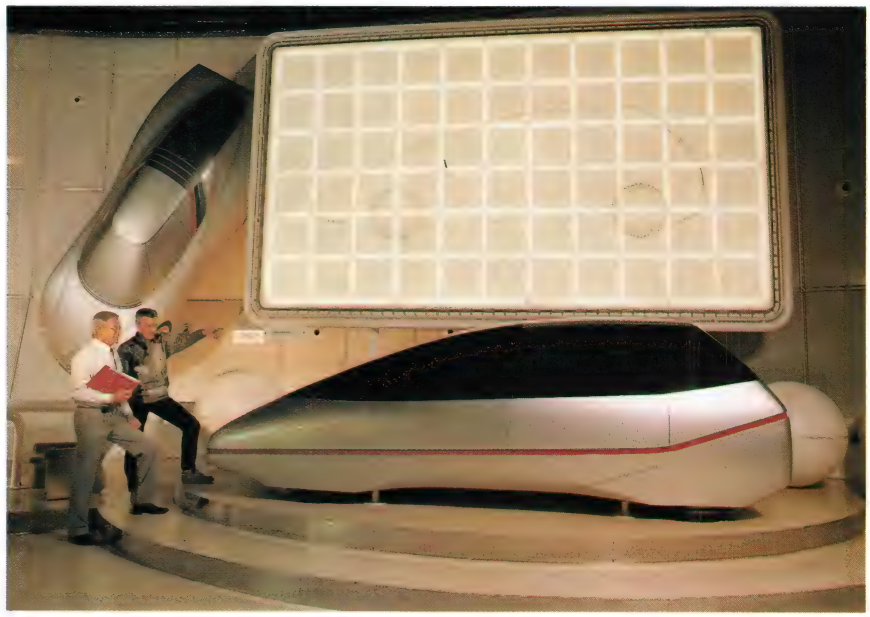
As well as giving a comfortable ride, the active system makes cornering safer. It can stiffen the car's suspension on a sharp bend or make the car lean into the bend, so countering the effects of centrifugal force on the occupants. The system also tilts the car forwards when the driver accelerates quickly and tilts it back during hard braking, once again countering the forces of motion.

Engine performance, too, is being monitored by computer on the latest models of cars. The computer checks the amount of fuel and air entering the engine, ensuring that the mixture is just right to achieve peak performance with good fuel economy and pollution control.

COMPUTER ERROR

On February 19, 1985, China Airlines Flight 006 was cruising on autopilot at a height of more than 12 km bound for Los Angeles, USA. Suddenly, without warning, the jumbo jet began to fall from the sky, plummeting more than 9 km in just two terrifying minutes before the pilot regained control.

An analysis of the plane's flight recorder revealed later what had gone wrong. The outer engine on the right wing had lost power. And although a Boeing-747 jumbo jet can fly manually on only three engines, it cannot do so with the autopilot engaged. The captain made the almost-fatal mistake of not taking over from the autopilot straight away – one instance of where the human, not the computer, should have been in charge.



Ivaldi/Jerrican

Sautelet/Jerrican

BMW's prototype *car of the future owes its special aerodynamic shape to CAD (computer aided design).*

Subaru's experimental car *relies on its in-built computer for active control of every function, from the engine and suspension to air conditioning.*

In-car monitor

In the newest generation of cars, much of the data picked up by various sensors is relayed to the driver through an instrument com-

Bob/Jerrican

Le Ciclop *is an experimental computerized navigation system for cars. The screen (below) displays a map, allowing the motorist to avoid congested routes.*

puter. This not only reports the usual readings – such as speed and fuel level – but also warns if something is wrong, or if a routine maintenance check is due.

Soon, car computers will be able to do 'smart' gear changes. As the driver shifts the four main gears, a computer will control three more intermediate gears for smoothness and better fuel economy. The shifts will be so quick that those in the car will not be aware of them.

Intelligent cars

Within ten years the onboard car computer will bring many automated refinements. For example, cars may be able to sense and respond to rain. When drops of water start to fall on the bonnet, pressure sensors will alert a computer to turn on the windscreen wipers. Similar devices in the passenger compartment will alter the shape of seats automatically to suit whoever is sitting in them. Computerized rear-view mirrors will adjust themselves to day and night driving.

Imagine you are driving a car fitted with a computer that acts as your guide. On the dashboard, you see a small TV screen displaying a street map, with a blinking light to mark your position. At the appropriate moment, instructions appear on the screen and, if desired, are 'spoken': 'Leave the motorway at the next exit. Then take the first turn left'.

Early warning

Some car navigation systems are already available. One called Carin, under development by the Dutch company Philips, can hold as much information as a shelf full of ordinary road maps. Eventually, the system will be able to pick up messages beamed from roadside beacons that will warn of traffic delays. Then the computer will plan routes to avoid them.

Such systems work out distances by measuring how may times the car's wheels have turned around, and find directions by taking readings from a compass. In the future, car travellers will be able to pinpoint their positions far more acurately by using satellite navigation systems.

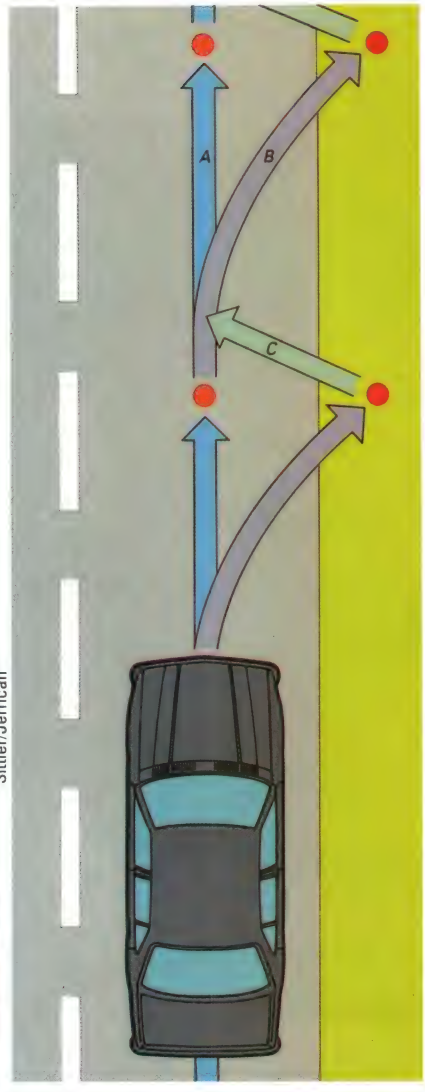
Signals at sea

Already, ships use this method to find their way at sea. A computer on the ship's bridge picks up signals sent out by a number of satellites in Earth orbit. The computer then calculates the vessel's position at any time of the day or night.

A network of 24 satellites, known as the Global Positioning System

Dagobert/French Railways

Computerized ticket *machines are a feature of railway booking halls throughout the world. The latest versions can issue change from banknotes.*



Sittler/Jerrican

Philips Carin

Carin *is a satellite navigation system. The correct route (**A**) is constantly checked and any steering errors (**B**) instantly corrected (**C**).*

Just amazing!

CAPTAIN CHIPS

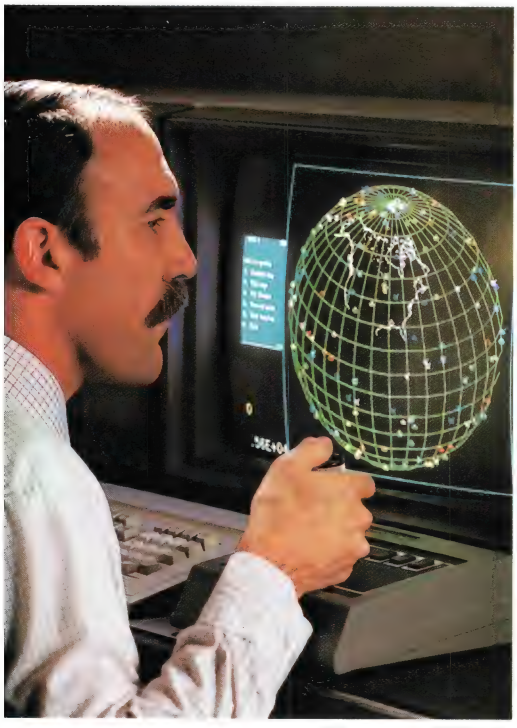
ON JANUARY 15, 1985, A COMPUTER SAFELY PILOTED A DUTCH FREIGHTER TO WITHIN A FEW KILOMETRES OF ITS DESTINATION – THE CREW HAVING ABANDONED SHIP TWO DAYS PREVIOUSLY.

Paul Raymonde

(GPS) began operating in the early 1990s. Then any ship, plane or car anywhere on Earth with the right onboard equipment will be able to find its true location to within about 100 metres.

The A320 airliner (the European Airbus) bristles with 'smart' electronics. Microprocessors — miniature computing units — built into the wings supervise the motors that operate the flaps and slats. By turning the flaps down or pulling the slats out, the pilot can give the Airbus increased lift. But if the pilot makes an error — for example, tries to pull back the slats below a safe speed — the microprocessors warn the flight crew that this action could be dangerous. The captain then has the choice of cancelling the procedure or repeating it to override the computer.

Robot trains *on the light railway system in Lille, France. Controllers monitor the progress of the trains, which run at one minute intervals, via computer terminals and video screens.*



A global positioning map *being used as part of a computerized navigation system to track patrolling military aircraft around the world.*

Eric Schulzinger/Lockheed Aeronautical Systems Co.

Active control

By the next century, there could be helicopters flying without human pilots in control. Passengers would simply tell a master computer on board where they want to go and the helicopter would take off, fly safely to its destination and land automatically.

The latest fighter planes take advantage of computer power — they are designed to be unstable to make them more agile. A test version of the British Aerospace Jaguar built in this way, for example, is 15 per cent lighter than a standard Jaguar and 20 per cent more responsive in turns. So it has a great advantage in aerial dogfights.

The problem with such an unstable plane is that no human pilot can fly it unaided. So, computers throughout the aircraft monitor every moving part many times each second, changing the control surfaces on the wings and tail as needed.

Fly-by-wire

With computers on hand, the pilot need never worry about going into a spin or swerving too fast. Even if he slams over the control stick too hard in the heat of combat, the 'fly-by-wire' system works out the steepest turn or climb that can be made without overstressing the aircraft, then responds in a split second to maintain a safe pattern of flight.

Computer control can make outmoded technologies once more attractive. A new generation of wind-assisted vessels is taking to the high seas, not with a large crew of sailors to set the sails, but with computers.

Pioneer of this approach to ocean transport is the Japanese tanker, *Shin Aitoku Maru*. Its two rigid sails, over 12 metres high and 8 metres wide, are canvas over a steel framework. On board, a system of computers adjusts the sails for best performance, throttling back the ship's diesel engine according to the force of the wind.

Ivaldi/Jerrican

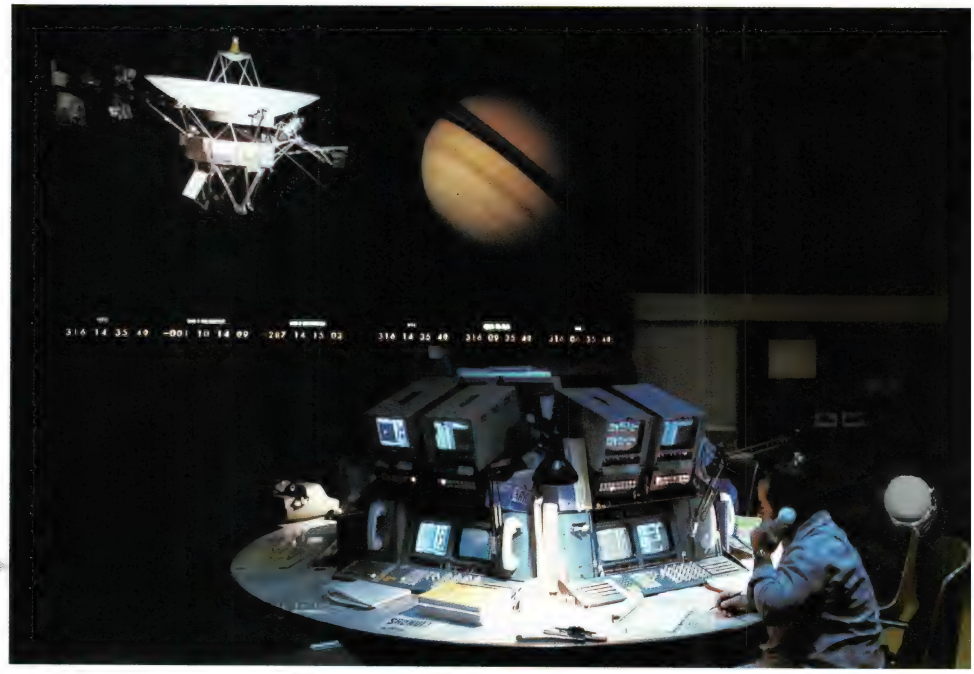
DRIVERLESS TRAINS

At Lille in France, fully automated commuter trains work safely and efficiently without a human driver at the wheel.

Computers keep track of the trains' positions and control both acceleration and braking to keep trains running exactly one minute apart during rush hours.

Staff in a central control room supervise the entire network, working with closed-circuit TV screens, an electronic chart of the rail system and computer consoles. By remote control, they can quickly deal with any problems or bring more trains into service to meet extra demand.

Peter Ryan/SPL



Mission control *at the Jet Propulsion Laboratory, California, USA, during the monitoring of the progress of the Voyager 1 spacecraft's encounter with the planet Saturn in November 1980.*

NUCLEAR SAFETY

THE EXTREME DANGERS involved in producing nuclear energy make the very highest standards in safety and security vitally important.

The production of nuclear energy in modern nuclear power stations relies on fission – the splitting of an atom into two roughly equal parts. Uranium–235 (U–235) is the form of uranium (called an isotope) most commonly used to achieve fission.

Atomic bullets

Electricity is generated from the heat produced when fission occurs in a chain reaction (a continuous process in which neutrons – nuclear particles – released by the fission of one atom go on to split other atoms). This heat turns water into steam, which powers the turbines that generate the electricity.

The major problem with nuclear power generation is not only that the U–235 is radioactive, but that the fission process produces other radioactive substances, and this radioactivity can be lethal. The greatest tasks in the nuclear industry are to contain the radioactivity – even in the event of an accident – and to control the chain reaction so it does not release all its fission energy in one surge – like a nuclear bomb.

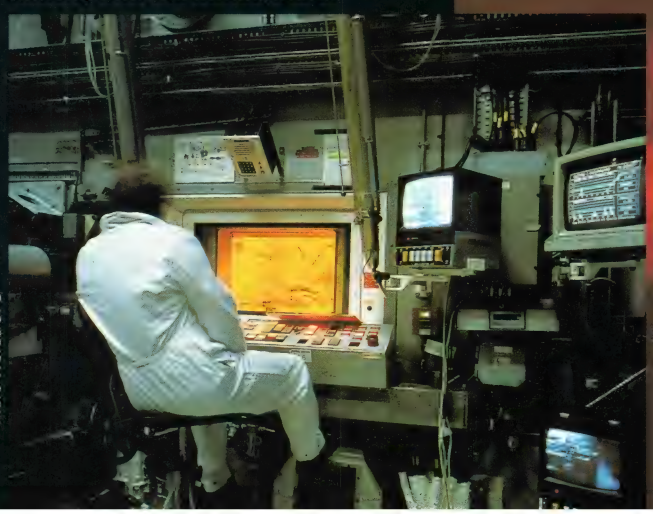
Cooling the core

The uranium fuel is in the form of pellets packed into stainless-steel rods. This type of packaging helps the fission process, and it also makes the material easier to handle. The fuel rods are grouped together inside the core of the reactor – the vessel in which controlled fission takes place. The core and its associated cooling system are contained in a thick concrete pressure vessel, which in turn is housed in a concrete building.

On 28 March 1978, at the Three Mile Island nuclear power plant in the USA, a failure in the reactor cooling system, combined with operator mistakes, severely damaged the reactor, releasing radioactivity into the atmosphere.

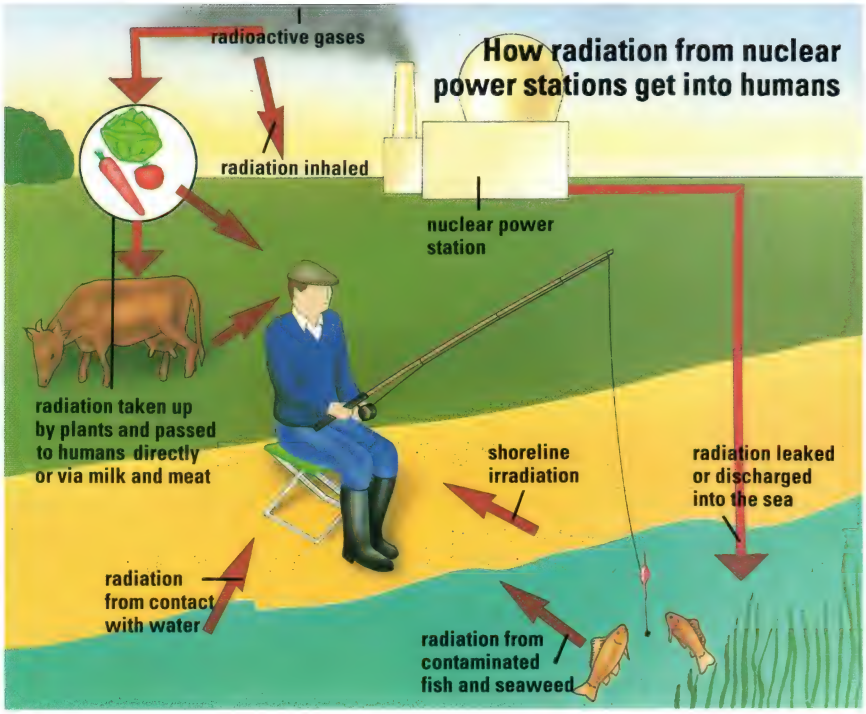
***A nuclear bomb** set off in the Nevada Desert, USA. In nuclear power stations, this tremendous amount of energy is released in a controlled way to produce steam for generating electricity.*

ZEFA



Mere Words SPL

***Remote handling gear,** controlled by staff using computer consoles, is used to unpack spent nuclear fuel elements (which are still highly radioactive) before they can be reprocessed.*



Mark Franklin

On 26 April 1986, operators of the nuclear plant at Chernobyl in the then Soviet Union were conducting an unauthorized experiment when the reactor went 'critical' – out of control – and exploded, releasing an enormous cloud of radioactive debris. Human errors like these have done little to further public confidence in the nuclear industry.

On the move

Another major area of concern is the transport of radioactive material. In Britain, for example, spent fuel rods are carried by train from power stations for reprocessing at a special plant. Reprocessing is necessary because during the fission process, the uranium is transformed into plutonium and waste materials. The reprocessing plant extracts the plutonium and any remaining uranium for future use, leaving the waste to be disposed of.

The spent fuel rods are transported in leak-proof flasks 2 metres high, 2½ metres long, 2 metres wide and weighing 50 tonnes. To reassure the public, the UK's Central Electricity Generating Board (CEGB) staged a crash of one of these flasks in the summer of 1984.

In full view of the press, television and public, a 140-tonne diesel train pulling three coaches was driven into a flask with an impact speed of 160km/h. The crash wrecked the train and threw the flask about 60 metres from the crash site – but the seals of the flask remained intact. During the past 35 years, the UK has moved more than 30,000 flasks of radioactive fuel.

Home-made nukes

One frequently expressed fear is whether a terrorist organization could steal material to make an atomic bomb. Each year, small amounts of nuclear material go missing. In 1965, for example, a check at the US reprocessing plant at Apollo, Pennsylvania, revealed that 94 kg of weapons-grade uranium had vanished from stock.

Missing material is thought to be diverted to countries such as Israel, Pakistan, India, South Africa and China. If terrorists get hold of material such as plutonium, it is possible that they could indeed build a gun-type nuclear weapon.

Radioactivity *can enter the environment in small doses over many years, or in large bursts by accident. This highly dangerous pollution can then pass into humans by any of a number of routes.*


Mere Words/SPL

A storage pond *for spent nuclear fuel awaiting reprocessing. The fuel elements are transferred from metal flasks in which they are transported, then lowered by an overhead crane into the water.*

Martin Bond/SPL

A metal flask *(white), into which spent nuclear fuel is transported by rail from nuclear power stations. The flasks are highly reinforced so they can withstand the impact of a crash without bursting. The useful part of the material is removed at a reprocessing plant, then the waste is stored in sealed containers.*

Just amazing!

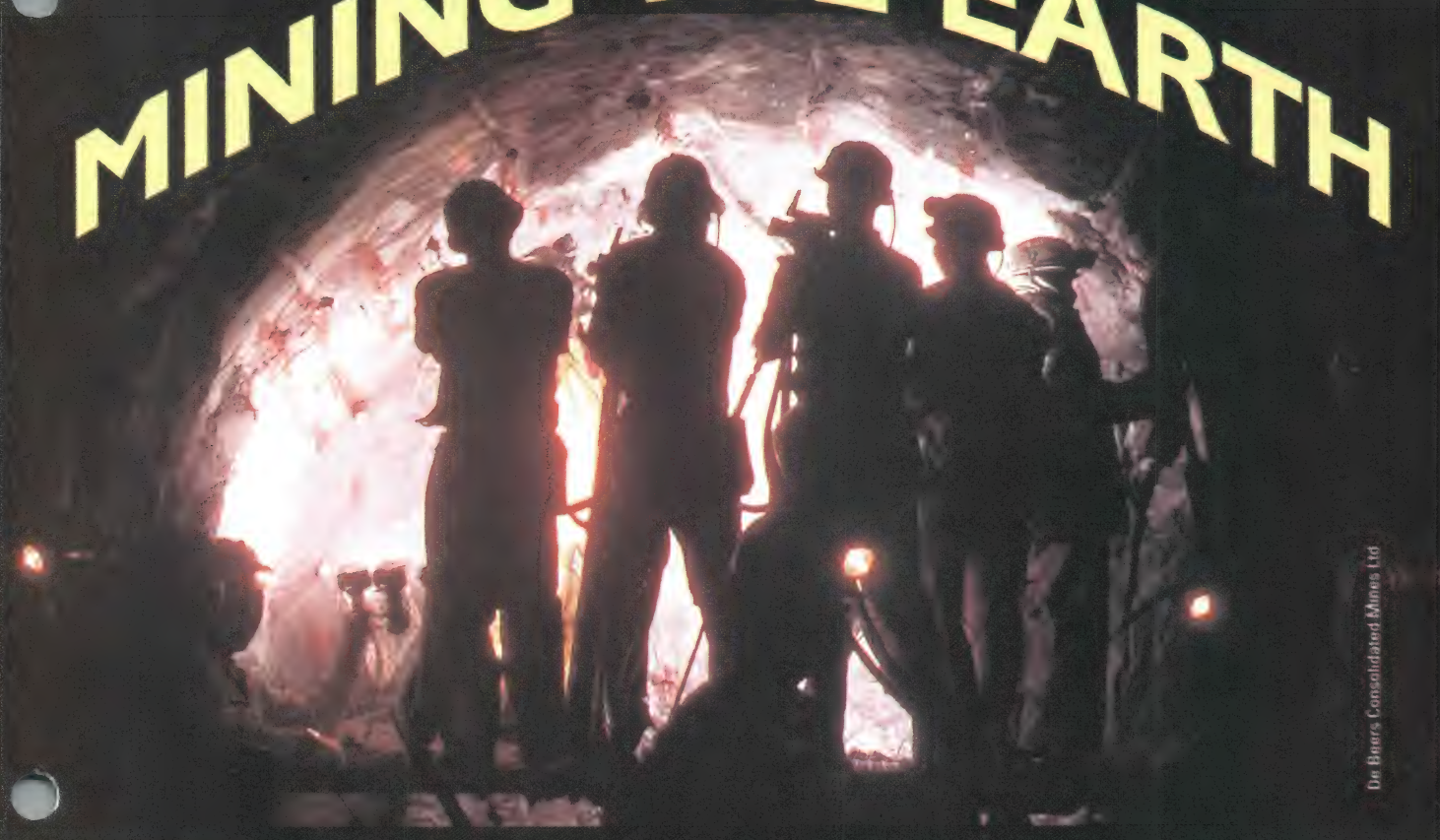
A BIG BANG

PLUTONIUM–239 MUST BE STORED OR HANDLED IN QUANTITIES OF LESS THAN 300 GRAMS – ABOUT THE WEIGHT OF A FIST-SIZED ROCK. HEAVIER AMOUNTS EXPLODE AS A NUCLEAR BOMB.


Paul Raymonde

FOSSIL FUELS | MINERAL DEPOSITS | MINING TECHNIQUES

MINING THE EARTH



De Beers Consolidated Mines Ltd

Cannon Consolidated Ltd

Miners drilling a diamond-bearing rock face deep underground. They break the rock into manageable sizes that can be lifted to the surface.

Mining machines come in all shapes and sizes. This electric drill has a left and a right drill arm so it can work on either side of a rock without having to turn around.

THE EARTH IS A HUGE BALL OF energy and minerals, which provide us with everything – from fuel for warmth to metals and plastics for industry.

The coal deposits now being mined are the remains of vast forests submerged beneath the Earth's surface. Most of the world's coal was formed about 300 million years ago. As the mass of vegetable matter became buried under more and more sediment, the combined effects of intense heat and extremely high pressure turned it first into peat then into coal.

Oil is the fuel of 20th-century transport. Like coal, it is a fossil fuel, but it is largely the product of fossilized marine lifeforms which have been buried below the sea bed to a depth of around 2 km. Usually, oil and gas are found trapped under nonporous shale, clay or dense rocks, such as limestone.

Mining for oil involves drilling wells deep into the crust to pierce the top of the trap containing it. The drill bit is lubricated with water or mud. When the drill hits a deposit, pressure within the well often forces the oil or gas to the surface. When the pressure subsides, the oil has to be pumped out.

Iron makes up about 5 per cent of the Earth's crust and is mined in large quantities to provide about 1000 million tonnes each year. Aluminium ore, known as bauxite, and copper ores are also heavily mined for industrial use.

Copper is becoming scarce and mining companies have literally moved mountains to win it. For example, in the village of Bougainville in the Solomon Islands, villagers were forced from their land and the jungle cover eradicated along with 40 million tonnes of surface material above the copper ore. But political disturbances led to the closure of the mine in 1989.

King of metals

Gold, the highly prized yellow metal, is found in grains, flakes and nuggets, but is scarce. To satisfy the demand for this metal, men work in deep mines, kilometres beneath the surface, in hot, wet and dangerous conditions. The same sites that contain gold may also contain uranium – a radioactive metal used in nuclear power plants.

Gold is extracted from the world's deepest mine at Carletonville in South Africa. Temperatures at

the bottom of this 3777-metre mine reach 55°C.

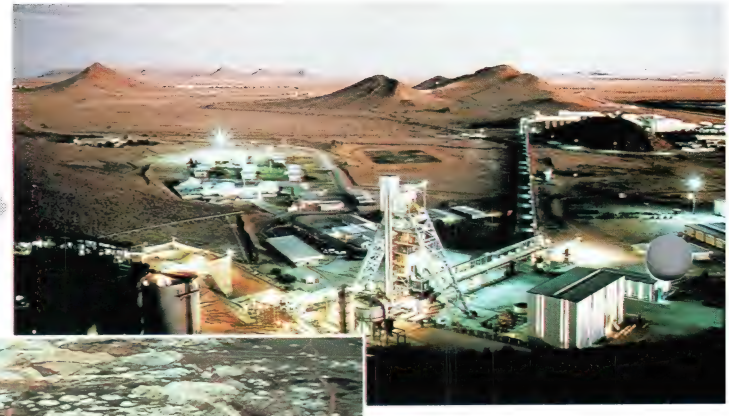
Diamond is the hardest substance known. It is a form of carbon – like soot or graphite – transformed by great heat and extremely high pressures deep within the Earth's crust. The top four diamond producing countries are Australia, Zaire, Botswana and the USSR.

Shock waves

To find minerals, prospectors set off underground explosions which send seismic waves, or shocks, through the rocks and soil. The waves pass through different materials at different speeds and are deflected by the material.

These echoes are picked up by microphones on the surface and analysed to build up a picture of the types of rock, soil and minerals in that area. Only if this type of survey indicates that minerals are present will engineers begin work.

The way in which minerals, including coal and most metals, are removed from the ground depends on the size, shape and location of the deposit. When minerals lie close to the Earth's surface, the vegetation and top layers of soil, sand and rock (known as the overburden) are removed so the ore can be dug out. This method is known as open-



The Black Mountain *metal mine in Africa where ore is mined underground and hoisted in ore skips to the surface. The ore is then conveyed to a mill and ground before shipment.*

Australian Overseas Information Service, London

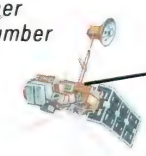
Mining for opals *in Australia has left a scar on the landscape which will take many years to put right. Australian white and black opals are world-famous as gemstones.*

Consolidated Gold Fields

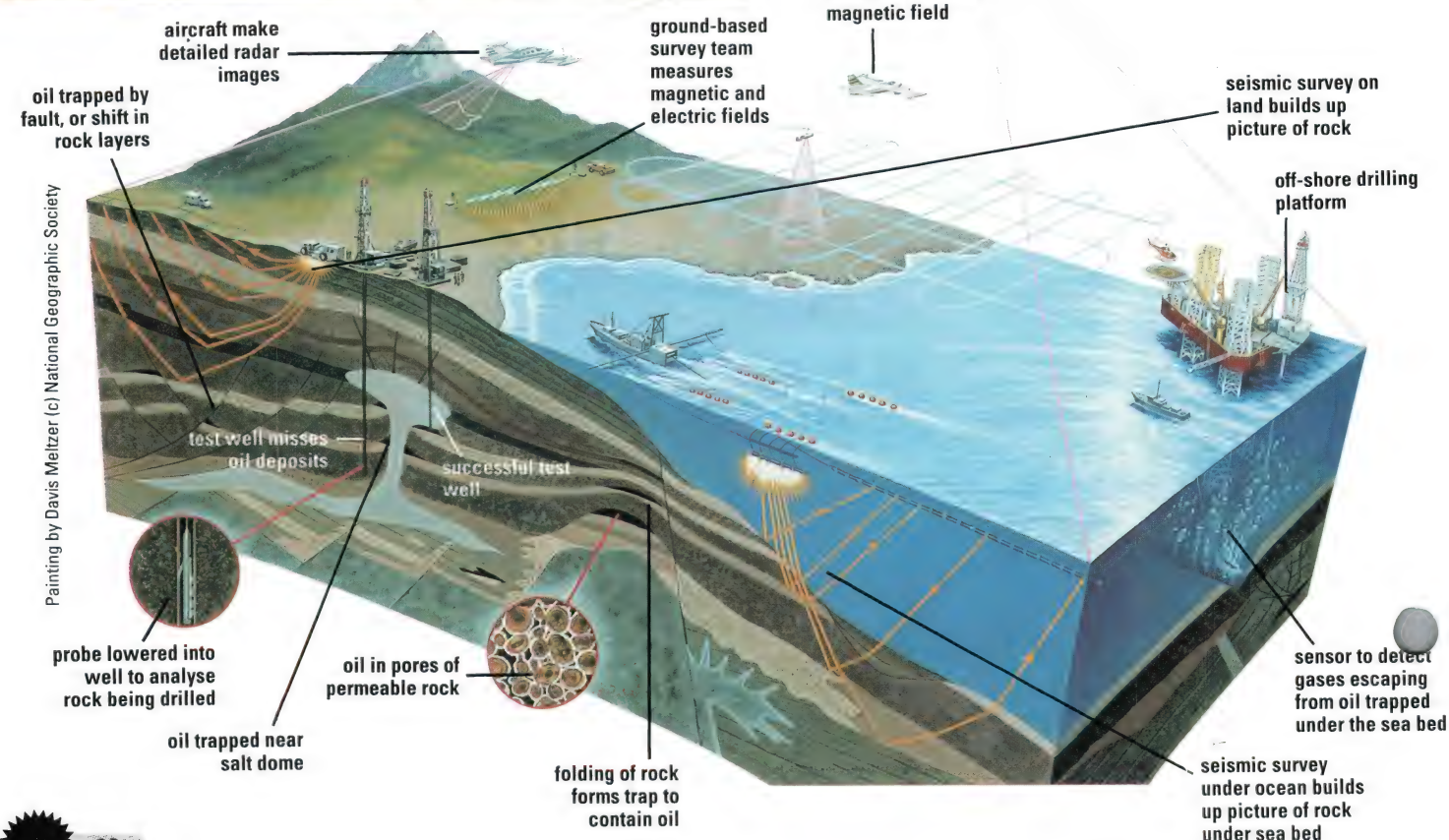
De Beers Consolidated Mines Ltd

A bucket-wheel *excavator scoops up sand and moves it along conveyors to expose ore containing diamonds.*

Locating oil *is a kind of detective work involving piecing together data from a number of tests and surveys.*



Searching for Oil



Painting by Davis Meltzer (c) National Geographic Society

cast, or open-pit, mining. It is basically a large-scale quarrying site, with huge bucket-wheel excavators on crawler tracks and other heavy vehicles digging and moving rock. Minerals such as aluminium, copper and iron are extracted by open-cast mining.

Big strippers

Strip mining is another form of open-cast mining in which the rock is drilled and blasted to loosen the material. It is then stripped or scraped out by giant drag lines, shovels or excavators.

Open-cast mining is very destructive of the environment. Sometimes when the mine is worked out, the waste rock and soil are replaced and the area is landscaped, but the disruption to plant and animal life takes many years to put right.

However, open-cast mining is cheaper than underground mining because much larger equipment can be used. So it is used wherever there are valuable minerals. About 70 per cent of ores come from surface mining where equipment can dig down to 500 metres.

To make deep mining worthwhile, the yield must be high or the product rare and expensive, like diamonds. Shafts, tunnels, lighting, ventilation and water pumps are all expensive requirements for deep mining. Deep mines are usually excavated to a depth of about 1,830 metres, although some diamond mines may be as deep as 3,050 metres.

Once the shaft has been dug, timber, steel and concrete pillars are used to support the rock and protect the workers. The ore or rock must be drilled or blasted to produce manageable-sized rock, which is carried to the surface by hoists on the main shaft. The drilling is usually done by pneumatic hammers.

Explosive power

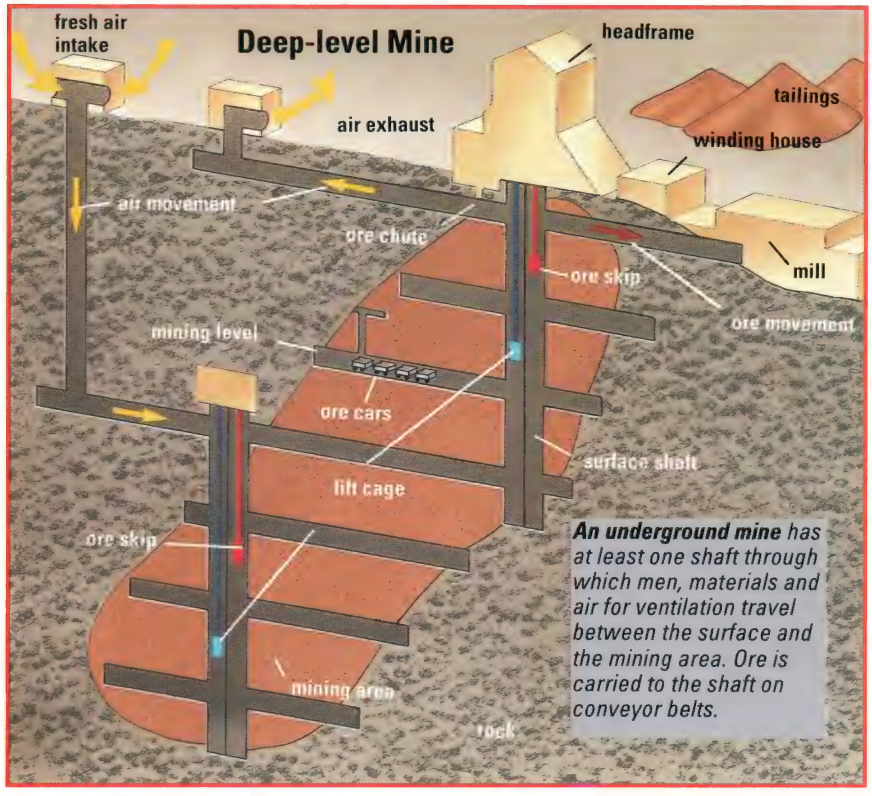
Blasting is sometimes used to free ore in underground mines. Holes drilled into the rock are filled with small explosive charges, which are set off to break up the rock. The location and angle of drill holes is determined by the type of rock, the number of rock faces exposed and the lines of weakness in the rock.

In large mines, electrical or battery-operated rail systems haul hundreds of tonnes of coal or ore into the main shaft. Conveyor belt systems are also common in coal mines. For continuous mining, some mines employ a track-mounted unit with teeth on rotating chains as the cutting head.

Once the cutting head has bored into the bottom of the rock face, it is gradually raised by hydraulic jacks to the top of the seam so it cuts out the material as it moves upwards. The chopped up material passes back over the teeth and chains on to a conveyor belt.

Gamma/Frank Spooner Pictures

***Fortune hunters** laden with soil they hope contains a golden nugget scramble up ladders in a Brazilian mine.*



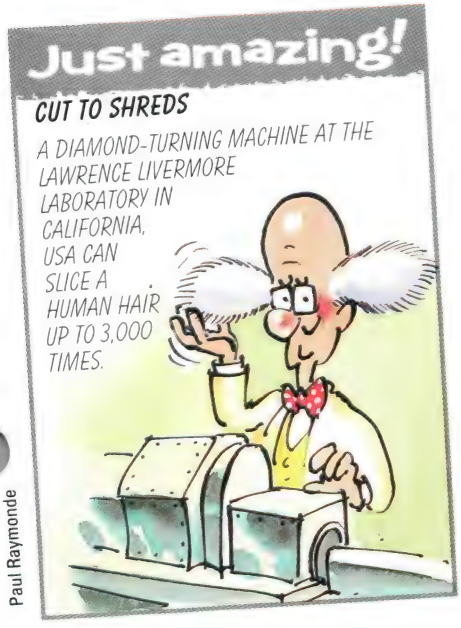
***An underground mine** has at least one shaft through which men, materials and air for ventilation travel between the surface and the mining area. Ore is carried to the shaft on conveyor belts.*

Mark Franklin

MINING DISASTER

Rex Features Ltd

The hazards of mining were brought home to residents in the Brazilian town of Maraba in 1986 when a disaster in the Serra Pelada mine, one of the world's most important open gold mines, claimed the lives of 50 people. The victims were engulfed by a mud slide, brought about by weeks of near-continuous heavy rain, as they dug and sifted ton after ton of earth in the hope of finding nuggets of gold in its uncombined, pure state.

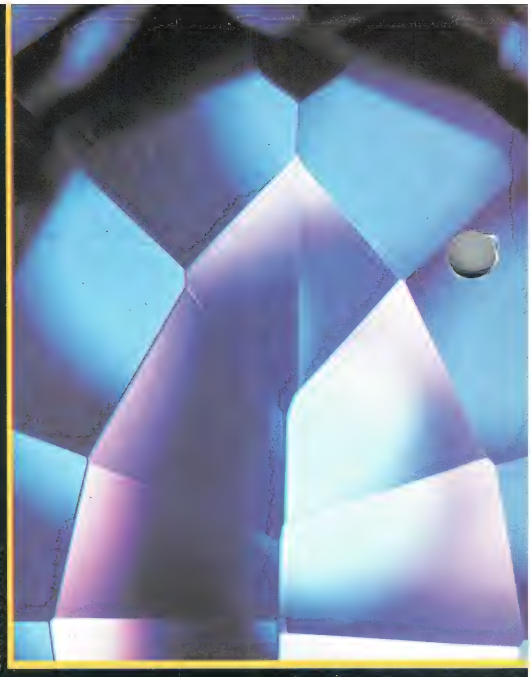


Paul Raymonde

ZEFA

Sapphire is a crystal of aluminium oxide, or corundum, naturally tinted blue. When tinted red, the mineral is called ruby.

A gold nugget found in its pure state because the metal is unaffected by moisture, oxygen and corrosion by acids in the soil.



John Walsh/SPL

The hexagonal crystals of vanadinite, a mineral found in Morocco, are formed by the oxidation of lead minerals.

Arnold Fisher/SPL

Pure crystals of quartz – the Earth's most abundant mineral – are a form of silicon dioxide. Crystals with impurities are coloured.

Arnold Fisher/SPL

Crocoite is deposited when hot solutions of chromic acid react with various lead minerals.

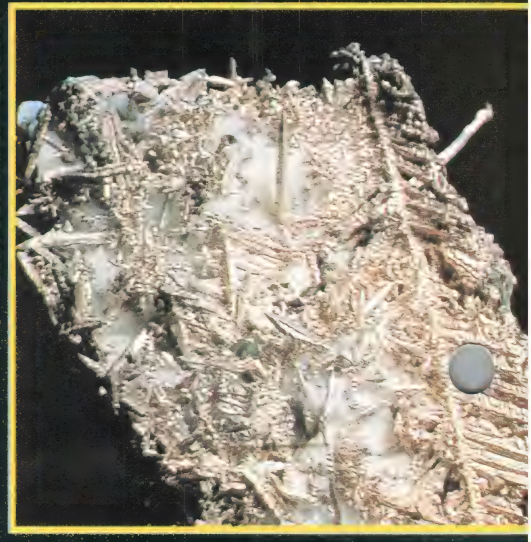
Uncut diamonds bear no relation to the sparkling gems that have been cut and polished to reflect light.

Sinclair Stammers/SPL

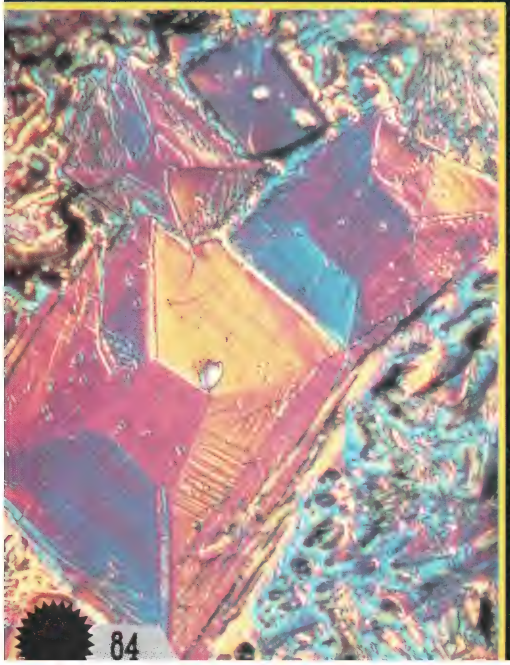
Arnold Fisher/SPL

Crystals of aluminium – a metal that occurs commonly as traces worldwide and is also concentrated in some areas.

Pure silver is found in large quantities in the Cobalt District of Ontario and in Russia and Mexico.

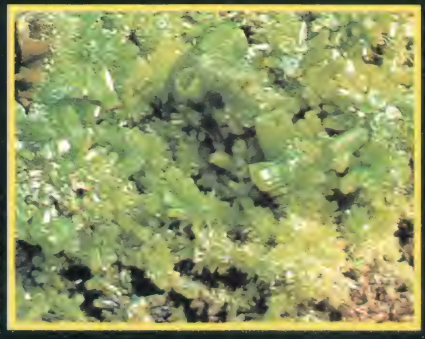


Geoscience Features Picture Library



Tony Stone Photo Library, London

Crystals of pyromorphite, a mineral formed by the action of water containing phosphoric acid on other lead minerals.



Arnold Fisher/SPL

BODY MAINTENANCE

- WEIGHT CONTROL
- FUEL REQUIREMENTS
- RELAXATION

THE HUMAN BODY RUNS automatically, in spite of its complexity. Yet regular maintenance is absolutely vital if the machine is not to break down or grind to a halt.

The body needs the right kind and quantity of fuel, rest at regular intervals, and exercise to keep it running smoothly. The better you look after it, the better it works.

The body needs food to provide it with energy. This energy powers a huge variety of everyday functions. Even when we are asleep the body needs energy, to pump blood around the body, to maintain the body at a constant temperature and to digest food. During strenuous exercise, the body may burn up 20 times the amount of energy used when at rest. Food is also used as building materials to repair the body and replace each one of its 75 million million cells.

Good health and weight control depends on a balanced diet, so that the right amount of energy is provided by the food consumed. There should also be the right balance between energy-rich foods such as carbohydrates and fats, and body-building and repair foods (proteins). A balanced meal contains around one part protein, one part fat, five parts carbohydrates and foods rich in minerals, vitamins and roughage.

Rough stuff

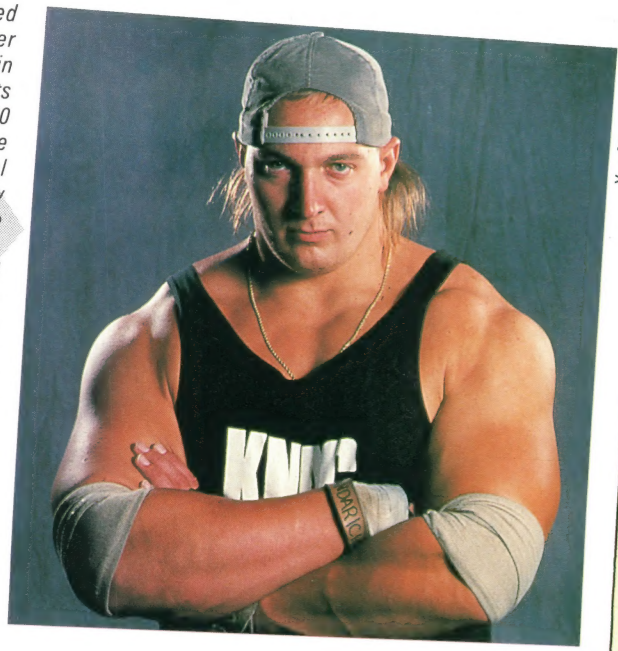
Roughage, or dietary fibre, is the part of unrefined cereals, fruits and vegetables that is not digested and passes almost unchanged through the digestive system. Roughage cleans out any food that may have lodged itself along the lining of the intestines. In this way, a high fibre diet helps prevent constipation and more serious disorders such as bowel cancer.

The energy value of food is measured in calories. One calorie is the amount of heat necessary to raise the temperature of 1 gm of water by 1°C. Strictly, calories are units too tiny to apply to quantities of food and what we normally refer to as calories are really kilocalories – one thousand calories. The number of calories in a particular food can be calculated by burning a certain weight of that food and measuring

Tony Stone Photo Library, London

Jean-Marc Barey/Allsport

***The dietary needs** of a swimmer (main picture) and a sumo wrestler (inset) are quite different – high-protein foods for the swimmer to build up muscle and lots of carbohydrates and fats for the sumo wrestler for bulk.*



Tony Mandarich, *regarded as possibly the best ever offensive tackle in American football, eats and drinks over 15,000 calories every day – five times a man's normal intake. The amount Tony eats and drinks in just one week is listed on the right. He is 1.98 metres tall and weighs 143 kg. 'The incredible bulk' eats to maintain this weight while training four hours a day in a gym. He claims never to have taken anabolic steroids to build up muscle power.*

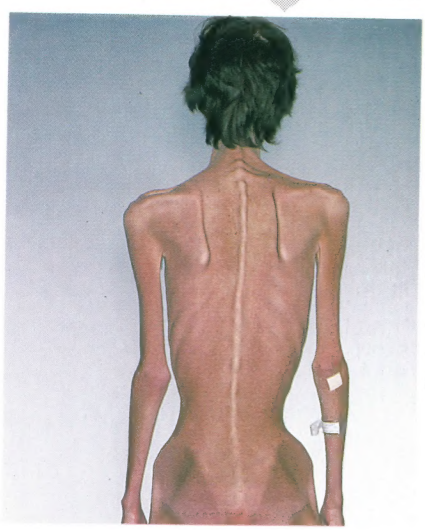
the amount of heat produced. A gram of protein or carbohydrate has 4.1 calories, whereas a gram of fat has 9.4 calories. So the body gains a lot more energy from 1 gram of fat than 1 gram of protein.

The amount of food, in terms of calories, that each individual needs to maintain a healthy body weight varies from person to person, partly depending on how much exercise that person takes. The average young man needs around 3,200 calories per day and the average woman 2,300 calories.

Balance

When more calories are taken in than burnt up, the body stores the excess as fat under the skin, around the muscles and around internal organs such as the heart and kidneys. If someone does not eat enough to balance the amount of energy he or she is expending, the body compensates by using up its stores of fat. If the calorie deficiency is extreme and the body's fat stores are exhausted, it begins to use protein as its source of energy. This protein is stored in muscles, so if the body has to use this, the muscles will lose their strength and waste away.

Anorexia nervosa *is known as the 'slimmer's disease'. Refusing to believe that they are seriously underweight, sufferers may be in danger of starving themselves to death.*



Charing Cross & Westminster Medical School

Exclusion diets

Many people are allergic to some foods, for example, dairy products or any food containing wheat. Typical symptoms are headaches, rashes or diarrhoea. To find out what the sufferer is allergic to, he may be advised to go on an exclusion diet. This includes only a few different foods – those least likely to cause an allergy. Then other foods are gradually reintroduced until the symptoms flare up again and the allergy has been pinpointed.

The body must be exercised regularly, like any other machine, or it will seize up. Exercise keeps the

John Houghton

Just amazing!

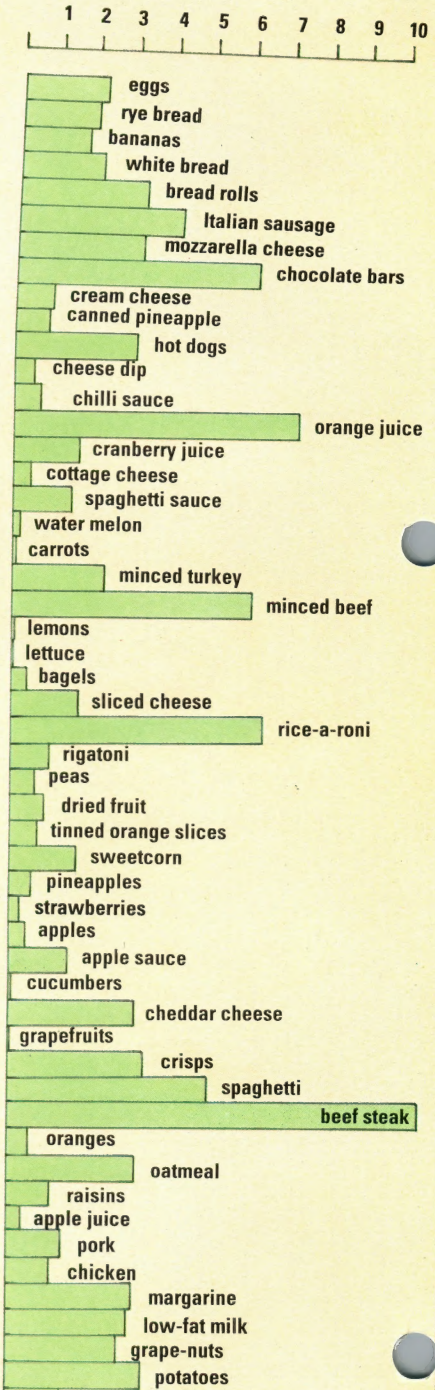
A HEAVY DRINKER

TO LOSE WEIGHT, ANGUS BARBIERI WENT FOR 382 DAYS WITHOUT EATING SOLID FOOD. HE LIVED ON TEA, COFFEE, WATER AND VITAMINS. HE WENT FROM 214.1 TO 80.74 KG, LOSING 133.36 KG – THE COMBINED WEIGHT OF TWO LESSER MEN!

Paul Raymonde

Tony Mandarich's weekly diet

You Magazine/Solo

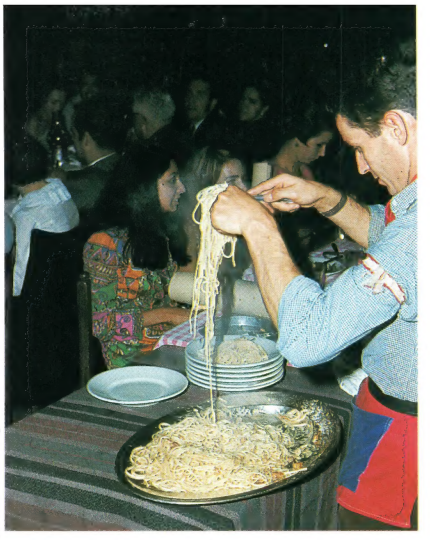


number of Calories eaten in a week	
by Tony Mandarich	108,000
by the average adult man	22,500

major joints lubricated, so that you can twist and turn and bend through a full range of movement. It maintains the strength of muscles and the efficiency of the heart and lungs.

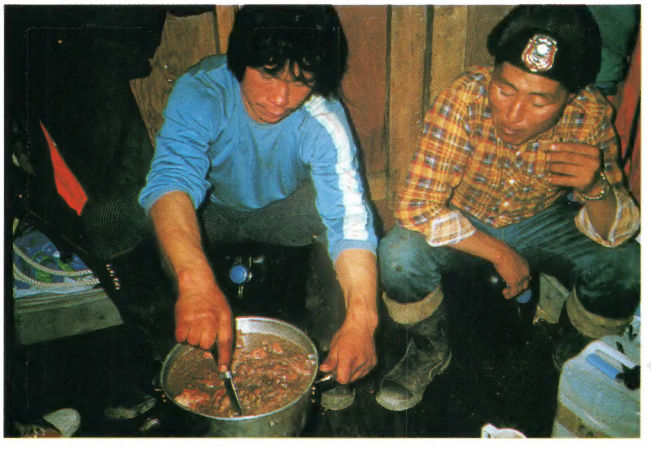
Oiling the machine

To keep the body in good physical condition does not need the dedication of an athlete – a few minutes a week devoted to a balanced exercise programme is sufficient. The typical posture of old age – hunched back, drooping head and round shoulders – caused by the joints stiffening up can be avoided by long-term regular exercise.



Robert Harding Picture Library

***Pasta** is made from flours, notably durum. It is a good source of complex carbohydrates and is fat-free.*



Gamma/Frank Spooner Pictures

***Eskimos** living in the Artic enjoy a diet based on meat and fish, eaten lightly boiled, raw or even frozen.*

The body is designed so that, when it is upright, the weight is distributed evenly over the supporting bones with the strongest bones taking the greatest weight. A sagging posture upsets this balance and can not only cause backache, but also constricts the chest, leading to breathing and digestion problems, and places unnecessary strain on other muscles. One method of improving the way we stand, walk, sit and talk is called the Alexander principle, named after the originator of this technique, F Matthias Alexander. Instructors claim that the correct alignment of the head and neck is crucial for the wellbeing of the whole body.

As well as exercise, the body needs rest. Deep relaxation is an essential counterbalance to everyday stress. People practising daily meditation have been monitored: during meditation each person's breathing slowed, the heart beat more slowly and (if he or she had high blood pressure) blood pressure dropped. Often, a bout of vigorous exercise brings on a feeling of complete relaxation afterwards.

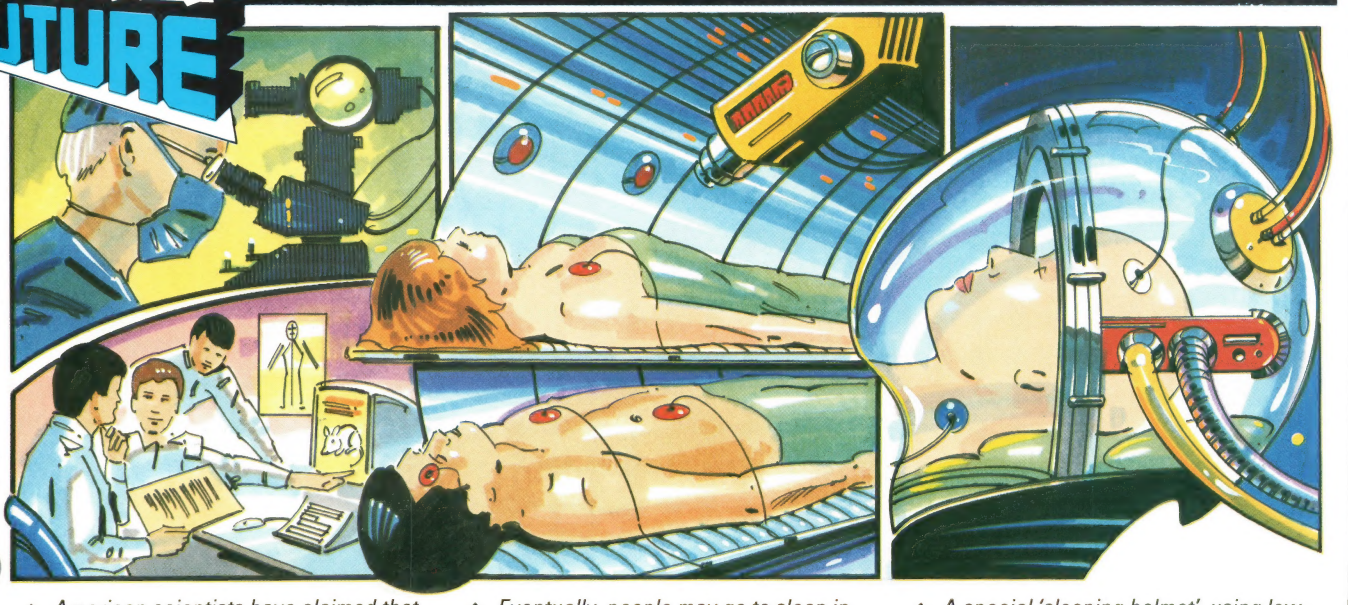
THE LONG-LIFE DIET

A low-calorie diet is the secret to long life, according to American gerontologist (old-age expert) Dr Roy Walford of the University of California. In his books, Dr Walford recommends a 1500-calorie-a-day diet, which is around half of what most adults eat. His theory is that a lean diet, made up of foods such as tofu (soya bean curd) and wholewheat pasta, will not only help you live longer but provide far more vitality.

Sleep is rest in its purest form. During sleep, growth hormones are carried by the blood to tissues and organs of the body, stimulating them to repair themselves and to grow. Children obviously do more growing than adults (particularly of bone tissue) and this is why they need more sleep. A one-year-old child needs 14 hours sleep in contrast to the 8 hours required by the average adult. After this period of renewal, the body awakes, ready to face a new day.

INTO THE FUTURE

THE SECRET OF LONGEVITY

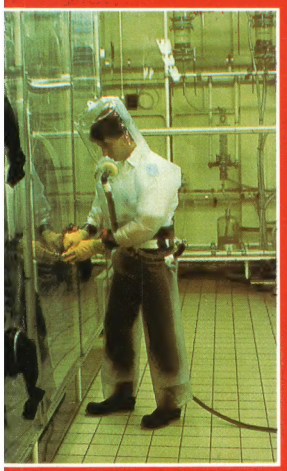


Joe Lawrence

▲ *American scientists have claimed that lowering body temperature slows down the ageing process – not only in mice, but in human beings too.*

▲ *Eventually, people may go to sleep in refrigerators, lowering their temperatures by several degrees – and so increase their lifespan to around 150 years.*

▲ *A special 'sleeping helmet', using low-power microwaves, will be worn to make the brain believe the body is warm. Thus the sleeper will not feel cold.*



Today/Rex Features

Nuclear *power workers, such as this maintenance engineer at the Sellafield plant in northern England, wear a totally enclosed suit and breathe a remote supply of oxygen.*

International Stock Exchange Photo Library

The flare *from the high voltage electric arc would blind a welder were he not viewing the workpiece through a very dark lens incorporated into a protective steel face shield.*

A de Meni/Science Photo Library

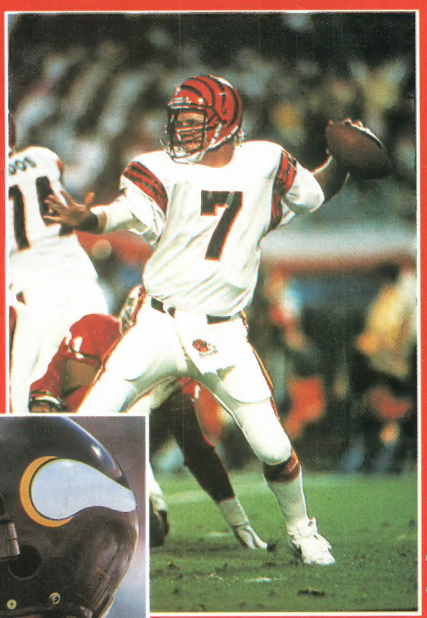
Asbestos*, in spite of its dangers, is the only material capable of offering protection from the extremely high temperatures of chemical fires.*

SCUBA divers *normally use a neoprene wet-suit to keep warm. By retaining millions of tiny air bubbles, neoprene acts as an insulator, preventing the loss of natural body heat.*

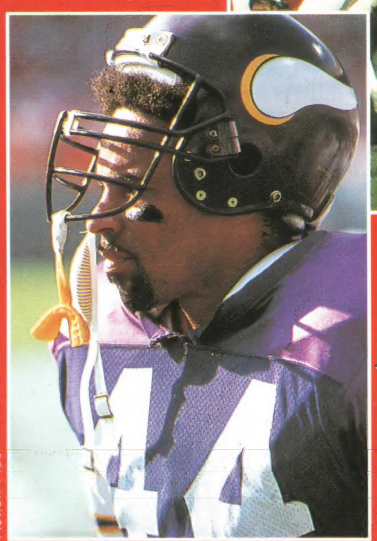
Mike Hewitt/Action-Plus

Steve Powell/Allsport

Insulation *is the key to retaining warmth in the air for hang glider pilots. Often, a close-fitting quilt is worn over a heavily padded flying suit.*



Rex Features



Action-Plus

American football *players face weights of 130 kg travelling at 35 km/h. Injury is avoided with body padding, crash helmets, face grilles, knee and elbow supports, shoulder, hip and thigh pads and boxing style gumshields.*

Action-Plus

Allsport/Vandystadt

The extreme cold, *of high altitude mountain climbing can be combated with many layers of clothing, firstly thermal and lastly wind and waterproof.*

Slalom skiers *need a well-insulated suit that is a close-fit to reduce drag, yet not too tight to restrict movement. Their ski boots have sensors that cause them to release in a fall.*